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DOUBLE-STACK CONTAINERS : CHANGING THE IMAGE OF INTERMODALISM

by

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March 1992

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Intermodalism is seen by some shippers as a new industry emerging within the transportation industry. This thesis provides a basic understanding of the intermodal industry and investigates how the advent of containerization, especially the double-stack container system, has affected the shipper's perception of domestic intermodal transportation. As the double-stack network spreads there are signs that this new industry may be able to resolve the problem of fragmentation which has prevented intermodal service from becoming cost-competitive. In addition, containerization and the use of double-stack trains can help streamline the rapid mobilization of military cargo.

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Double -Stack Containers: Changing the Image of Intermodalism

by

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ABSTRACT

Intermodalism is seen by some shippers as a new industry emerging within the transportation industry. This thesis provides a basic understanding of the intermodal industry and investigates how the advent of containerization, especially the double-stack container system, has affected the shipper's perception of domestic intermodal transportation. As the double-stack network spreads there are signs that this new industry may be able to resolve the problem of fragmentation which has prevented intermodal service from becoming cost-competitive. In addition, containerization and the use of double-stack trains can help streamline the rapid mobilization of military cargo.

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I. INTRODUCTION

A. BACKGROUND

Today, shifting trade patterns and globalization are creating new needs for intermodalism. There are new opportunities and potential profits for carriers that can provide this dependable, high-quality, value-added service.

To provide this type of service, containerization is the baton which can be quickly passed from one mode to the next during transport. Containers are essential and their use appears to be progressing with technological advances and creativity. The advent of the double-stack container system has rapidly expanded in recent years due to improved technology. As the double-stack network spreads there are signs that this new industry may be able to resolve the problem of fragmentation which has prevented domestic intermodal service from becoming more cost competitive. This research investigates facts to determine the contribution of domestic double-stack containerization to the efficiency and effectiveness of today's intermodal system.

B. OBJECTIVES

The main objective of this thesis is to acquaint readers with the intermodal system, and to investigate the double-stack relationships within the intermodal system. Peripheral issues such as the Intermodal Transportation

Efficiency Act and military applicability are also addressed.

C. RESEARCH QUESTION

The research covers areas of intermodal transportation and the changes occurring due to the advent of the double-stack container system. The primary research question is to determine if double-stack has changed the science of intermodality. Secondary questions pertinent to the subject include: Is double-stack more economical than trucks; and what efficiencies do double-stack container trains provide operators and shippers.

D. SCOPE

The scope of this thesis is to research and build an understanding of the emerging intermodal industry and to investigate how the advent of containerization, especially the double-stack container system, has affected the shipper's perception of domestic intermodal transportation as an alternative to trucks. The scope includes compatibility issues associated with containerization and the double-stack system. Also, military use of containers and intermodal systems are briefly discussed.

It is anticipated that the character of this thesis is general enough to provide thought provoking reading for a broad audience. However, limitations prevent expanding the background to encompass a review of the entire intermodal freight transportation industry. The greatest benefit will

be to individuals with some background in container cargo movements.

E. METHODOLOGY

Data accumulation for the intermodal and the double-stack network includes a comprehensive review of published literature with complementary telephone and personal interviews of representatives in the ocean carrier, ocean terminal, and railroad companies. Published information are limited to non-proprietary and unclassified data.

F. ORGANIZATION

This thesis incorporates seven chapters. Chapter II provides a general overview of intermodal systems with discussions on the air, land, and ocean legs. Chapter III discusses the development of the double-stack concept by the ocean carriers and railroads. Chapter IV describes the double-stack network and the growth involved. Chapter V explores the compatibility relationships faced with the growth of domestic containerization. Chapter VI describes and interprets the cost factors dealing with the double stack decision, focusing on the competition between double-stack and long-haul truck transport. Chapter VII presents a summary, conclusions, and recommendations.

II. OVERVIEW OF THE CURRENT INTERMODAL SYSTEM

A. INTRODUCTION

Intermodalism is seen by some shippers as a new industry emerging within the transportation industry. Intermodal transportation can be defined simply as "Through transportation movement involving more than one mode (e.g., rail, motor, motor-air, or rail water)" with a smooth transition, thereby, minimizing door-to-door delivery time. [Ref.1:p.113] A smooth transition between modes of travel is essential to provide quick and dependable service to shippers. Today, shifting trade patterns and globalization are creating new needs for intermodalism. There are new opportunities and potential profits for carriers that can provide this dependable, high-quality, value-added service.

Currently, the transportation industry subdivides intermodal service into two types; domestic and international. Experts disagree as to which area dominates intermodalism, but as global markets open up, the distinctions between the two sectors will blur due to international and domestic cargoes sharing the same corridors. "Intermodalism will not continue to evolve simply as an extension of the container shipping business or just as an extension of a traditional railroad operator" [Ref.2:p.58] and, as intermodalism evolves into its own

industry, there are expected to be great improvement in such areas as equipment standardization and service quality.

To provide this type of service, the container is the baton which can be quickly passed from one mode to the next during transport. Containers are essential in intermodal transportation and their use appears to be increasing with technological advances in containers designs and creativity. In fact, these advances has brought about new potentials in present intermodal capabilities with the advent of the double-stack container system (standardized containers are stacked two-high on special designed railcars) which has rapidly expanded in recent years due to improved technology and the opening of new rail routes which have double-stack clearances.[Ref.3:p.14]

As the double-stack network spreads across North America, there are signs that this new industry may be able to resolve the problem of intermodal fragmentation. This has prevented intermodal service from becoming truck-competitive. In order to be truck-competitive, the intermodal firm must meet changing customer needs with both comprehensive, precise, reliable and timely transportation, while also providing total logistics management services.

Today, customers des..re flexible, responsive transportation with matching networks that can take materials and products around the world, not only port-to-port but door-to-door.[Ref.4:p.17] These customers also

require a true global carrier, one that can move goods across major intercontinental trade lanes.

This chapter seeks to provide an understanding of the emerging intermodal industry. We will first investigate the history of intermodalism, the events and conditions motivating the adaptation to containerization, and then build an understanding of how each major container carrying mode is tied into the intermodal industry. The U.S. military's progression toward intermodal and the trend toward container use will then be discussed at the end of the chapter.

B. INTERMODAL HISTORY

Contrary to popular belief, intermodal transportation is not new. The movement to settle the American western frontier along with the beginning of the Industrial Revolution, gave rise to the development of intermodal containerization.[Ref.5:p.5] Ferries, for example, have been available a long time and are known to have carried boxed cargo, wagons containing cargo, and railcars.

A more significant example was the Pennsylvania Public Works which was an intermodal system connecting Philadelphia and Pittsburgh by a system of canals and railroads. The Pennsylvania Public Works Canal opened in 1839 and involved the use of barges as intermodal containers. The barges, loaded with a mix of people and cargo, functioned as containers as they were loaded as units aboard wagons,

railroads, and on the canals to provide better door-to-door service. The carrying structures were canal barges built in sections. In movements by rail, usually over areas where it was not feasible to construct a canal, barge sections were mounted on flat cars and carried to the next canal.[Ref.5:pp.6-7]

However, when competing with the all-water Erie Canal and, later, with all-rail routes, it turned out that the Pennsylvania Public Works system was not cost-effective. [Ref.5:p.10] Parts of the system were gradually abandoned and, by the end of the nineteenth century, this early intermodal system had largely passed into history.

Following World War II, several economic factors combined to create a favorable environment for intermodal transportation. One factor was the rapid increase in labor costs, particularly stevedoring. Another was the explosive growth in world trade with an attendant demand for faster and more economical service.

The third factor was the need for cargo security. Even as early as the 1950's, losses from cargo pilferage were estimated in the billions of dollars.[Ref.6:p.111] What seemed to be needed was a load-carrying structure that could be easily transferred from one transport mode to another without the necessity of breaking down and transferring the cargo.

With the United States, one method of cargo transport that became popular at the time was trailer-on-flatcar (TOFC), or the "piggybacking" of truck trailers on specially equipped rail flatcars. In June 1960 TOFC was offered by 51 railroads in the United States and has continued to grow steadily. TOFC operations were responsible for hauling nearly 80,000 trailers during the first 8 weeks of 1960, a 48.6 percent increase above the same period in 1959.[Ref.7:p.328] TOFC was efficiently used for highway and rail intermodal transfers and was designed for land intermodal transport efficiency. However, TOFC is not as efficient on the land-sea transfer as are containers.

One alternative to TOFC is the Roadrailer. The Roadrailer used a specialized highway semitrailer with a pair of steel railroad wheels that could be lowered so the trailer could ride on railroad tracks as well. The Roadrailer is an example of "carless" service. A rather substantial fleet of these Roadrailers was constructed, mainly to haul mail and parcel traffic behind passenger trains operating in North Dakota, Minnesota, and Wisconsin. [Ref.8:p.16] The Roadrailers were first used in the late 1950's behind passenger trains. The Chesapeake and Ohio Railroad (C&O: a forerunner of today's CSX corporation) developed this rail-highway vehicle. Their Roadrailer service lasted until the mid-1960's when passenger train service was largely discontinued. Because the design was

proprietary, it was not picked up by other companies until the patents were acquired and a more up-to-date version could be designed.[Ref.9:p.49]

In international transportation, the primary disadvantage of both TOFC and Roadrailer is that they must be either driven on or carried on RO/RO (Roll-On/Roll-Off) ships with relatively high cost and inefficient space use. There are also delays in the transition time between modes of transportation.

A new method was needed to cut down on the time it took to relay the cargo between all modes; air, land, and water. This need was filled by the creation of the container which took on many different sizes and designs to meet different cargo carrying requirements.

C. CONTAINERIZATION

1. Overview

The advent of containerization was a turning point in intermodalism. The use of containers for ocean cargo and intermodal purposes was not widely practiced until the 1956 container revolution. Even then, it was quite some time before intermodal containers were used on all ocean routes serving the United States. In the mid-1970's, containerization also took to the air. With the inauguration of container air service, though limited, the commercial container distribution system became truly intermodal.[Ref.9:p.113]

Containerization proved to have the qualities and practicality in which smooth transferring of cargo, between all modes, was possible. The creativity and versatility of modern containers offered solutions to many problems and helped in revitalizing intermodalism.[Ref.9:p.51]

2. Advantages of Containers

The driving force behind the development of containerization as an active transportation concept was the interest on the part of both shipper and the carrier to reduce costs involved in the ocean shipment of cargo. By substantially reducing cargo handling requirements, not only have cargo handling costs been reduced for shippers, but port turn-around times have been reduced tremendously for carriers.[Ref.10:p.18]

Because a container is locked and sealed at the point of origin and remains so until its arrival at its final destination, pilferage has been substantially reduced in situations where past transfers required cargo handling. Although pilferage does still occur, it can generally be traced to either the loading or unloading of the container, rather than during transport.

Cargo damage has been substantially reduced as well. Although some shoring is still required for cargo loaded into containers, cargo consignors are better able to mix and match their cargo to ensure maximum use of container capacity. The tighter the cargo can be loaded, the less

damage that is likely to result from cargo movement in transit. Additionally, because containers are handled mechanically, there tends to be less stevedoring damage to containerized cargo.[Ref.11:p.18] The container also protects the cargo from the elements.

There are some less obvious advantages to containerized freight. Containerized shiploading is a great advance over breakbulk loading in that it reduces time in port and gives ships more productive time at sea. Since containers are intact and hold inventory for the duration of transport, it can also be looked at as warehousing on the move adding another advantage seen by shippers. Of coarse the intermodal advantage of containers is that they provide efficient transfer between modes while facilitating the unitization of freight.

3. Disadvantages of Containers

The tremendous capital investment required to support containerization is a primary disadvantage of the system.[Ref.10:p.19] Because containerization is a capital intensive industry, relying on specialized equipment, rather than a labor intensive industry, all participants experience high start-up costs. Special equipment has had to be designed and purchased by both ship owners and port operators for the movement of containers. This equipment, which must be capable of handling fully loaded containers, must also have a high degree of reliability when faced with

the ever increasing numbers of containers moving through the ports.

4. Containers Used in Double-Stack System

The advent of the double-stack container system has dramatically altered intermodal transportation. The idea of double-stack containers has worked well with international trade but there were many skeptics in domestic transportation. As late as 1985, railroad officials, with the exception of Union Pacific, categorically stated that domestic double-stacked container movements would never happen in this country.[Ref.10:p.17] The consensus was, basically, that the stack train was nothing more than "a flash in the pan" that would never work on a broad scale. However, by 1990 the number of domestic containers, which can be double-stacked, had grown to 20,000 units. By 1994, about 60,000 of these domestic containers are expected to be in use.[Ref.10:p.17]

Because the use of domestic containerization has been steadily growing, positive benefits, such as greater savings, are being seen by both shippers and carriers. With international trade slowing from the torrid pace of the last two years, intermodal carriers are battling to recapture freight now moving over the road. With advancements in technology and service we can expect freight to be diverted from strictly highway transportation to intermodal transportation.

D. MODAL USES OF CONTAINERS

1. Intermodal Ocean Leg

Ocean shipping was the driving force behind intermodal transport. This will subside to an extent as the domestic transportation industry becomes integrated through intermodal networks. However, the ocean carrier will still have a major role in the shaping of intermodalism. As more cargo is containerized, larger vessels will appear in liner shipping.[Ref.12:p.1a] Over the next five years the overall capacity of the world containership fleet is expected to grow 25 percent. This growth may result in over-capacity in the industry.[Ref.12:p.1a] U.S. Flag vessels will probably be most affected should this overcapacity come about, due to decreasing U.S. Flag participation. Despite an increase in oceanborne cargo "tonnage" carried in U.S. Flag vessels of four percent in 1986 and another one percent in 1987, U.S. Flag participation in liner "service" fell below twenty percent for the first time in 1986 and dropped further to 14.9 percent in 1987. [Ref.13:pp.12-13] Figure 2.1 displays this trend.

Containerization has increased port productivity but, in the mean time, has required increased capital investment. Investments in the intermodal ocean system include the containers, the containership, the cranes for vessel loading, a large container storage area, and container handling equipment. One or more land carriers are

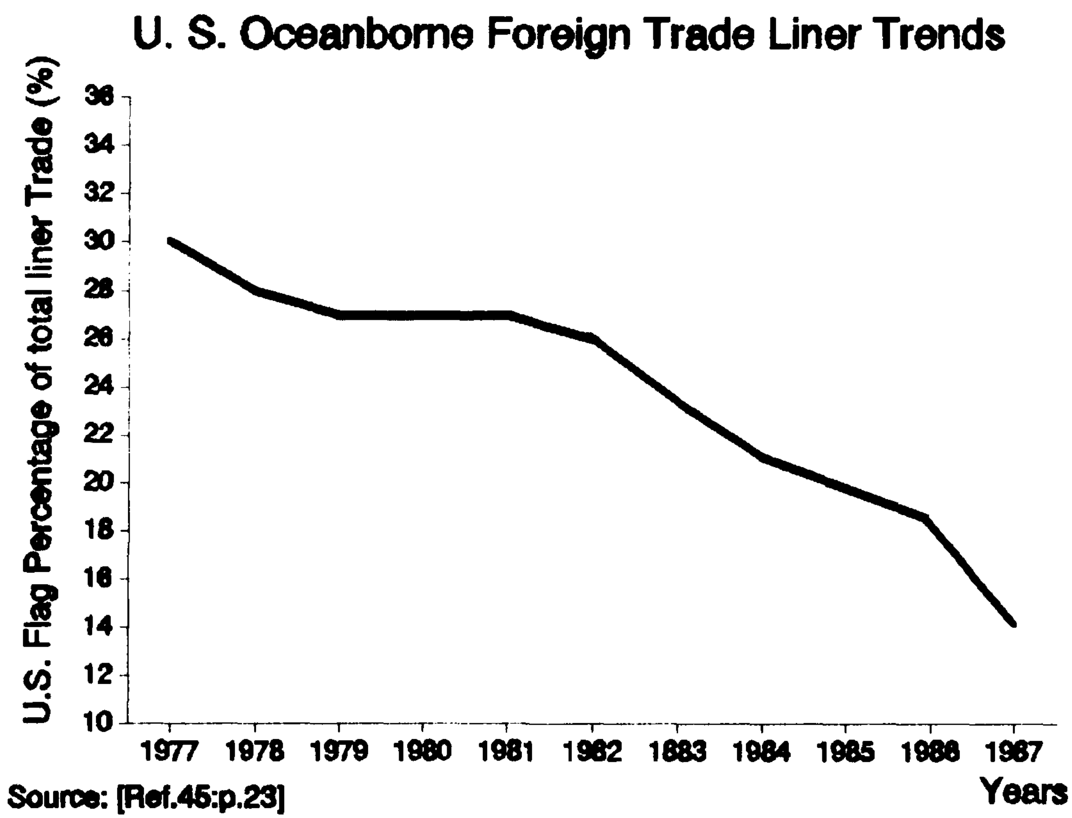


Figure 2.1. U.S. Oceanborne Foreign Trade Liner Trends.

also required to move the containers to and from the container port.[Ref.16:p.251] Intermodal ocean systems have other options such as RO/RO and LASH (Lighter Aboard Ship), however, the cubic space utilization is not as efficient as a container ship.

In spite of the high capital investment required, liner steamship companies, reacting to shipper preferences, have invested massively in containerization over the past 20 years.[Ref.14:p.17] Beginning with higher valued cargoes and working downward, virtually every kind of cargo moving in liner service became containerized. Military cargo, both routine re-supply and emergency mobilization stores, have also become containerized.[Ref.11:pp.21-23]

In the containership system, cargo maybe loaded, or stuffed, into a standard-size container at an inland point of origin. This is usually done at the shipper's warehouse or plant. The containers are then moved by rail or truck to an ocean terminal. Finally, the containers are loaded aboard a containership for movement to an overseas destination where they are unloaded at a container terminal and, eventually, loaded on a land carrier for delivery to an ultimate destination.

The total weight of the container and its cargo are extremely important due to stability requirements on ocean vessels. The weight categories are established by the steamship line to ensure proper control of stowage. The

container weight is also a concern with respect to the load carrying capacity of the equipment which will handle the containers during movement both in the yard storage area and over-the-road.[Ref.15:p.102]

2. Intermodal Air Leg

Air intermodal is still in its infancy, but it merits mention. The primary aircraft are the Boing 747F and the McDonnel Douglas DC-10-30AF all-freight carriers. [Ref.6:p.113] The 747 freighters or 747 combi-airplanes with main-deck cargo capability can efficiently hold two 8x8x20-foot air containers side-by-side. However, the Douglas DC-10-30AF is less economical since containers must be positioned along the center line, wasting space on both sides of the container.

The components of the intermodal air system are the standard air container, the airplane, the air freight terminal, and special container-handling equipment for loading and unloading the airplane.[Ref.9:p.114] Cargo is loaded in standard air containers and moved to the airport by a highway carrier, where it is loaded aboard the airplane for the long leg of its trip. On arrival at the destination airport, it is unloaded onto a highway carrier for delivery to the final destination.

Since air carriers are more affected by the line-haul cargo/container weight than are carriers in other modes, the standard intermodal air container is a lighter

8x8x20-foot box which weighs only about 2,200 pounds rather than the 5,000 pounds of a standard surface container. [Ref.9:p.172] These containers are four to five times more expensive than surface containers due to the specialized structure and other design elements required to lighten the total empty weight. However, the intermodal air containers are more susceptible to damage because of this lightweight construction. [Ref.9:p.172]

Although these intermodal air containers are available, most transfer between air and surface modes usually takes place without benefit of intermodal containers. Cargo may be containerized in air containers while it is moving in a surface vehicle, but the cargo usually is transferred in loose form because of the inability of the more popular 727's and DC-9's to carry 8x8x20-foot intermodal air containers.[Ref.9:p.58] A study was conducted by Air Transport Association of America (ATA) of air carriers transporting containers under container tariffs. They found that more than 40 percent of air carriers freight volume in 1982 was containerized, this was up from 33 percent in 1977. However, these containers generally were not used for intermodal purposes except within the confines of an airport.[Ref.9:p.53]

Intermodal air-surface container services started off encouragingly when hundreds of 8x8x20-foot intermodal air containers were acquired by major airlines during the

1970's. Experiments involving 8x8x20-foot container movements of air shipments combined with truck, sea, and rail piggyback were successful. One example is the well-publicized contract that involved General Motors, Alitalia and Lufthansa. Both airlines started an airbridge connection from Europe to Detroit, making three flights a week with Pininfarnia-designed car bodies for Cadillac. Boeing 747s carried car bodies in 8x8x20-foot containers on each flight to Detroit, and brought back 90 tons of automobile components on the return journey in the air containers.[Ref.17:p.45] However, use of these containers for intermodal purposes declined steadily due to costs, preferences, and inability to maximize cubic volume. It is evident that design and technical changes are needed to salvage future intermodal air container use.

Although the intermodal air containers are not significantly used today, the demand for quick door-to-door pickup and delivery with guaranteed delivery schedule and freight security demonstrates the potential of such containers. In the future an effective air-container will need to be designed to meet these demands.[Ref.9:p.176]

3. Intermodal Land Leg

The land intermodal system is composed of railroads that can transport either containers or truck trailers. Highway carriers can also truck containers directly from origin to ports for ocean travel. Generally however, the

railroad moves cargo over the long leg of the journey, within the U.S., and the highway carrier transports the container or trailer from the point of origin to the rail terminal and, at the end of the rail journey, from the terminal to the final destination. Components of the land system include the container or wheeled trailer, container chassis, the highway carrier, the rail carrier, a container and/or trailer rail terminal, and specialized container-handling equipment.

Between 1978 and 1987, intermodal rail carloadings expanded from 8 percent to over 16 percent of total railroad carloadings. This trend resulted in the resurgence of railroad transportation in the last few years. Improved equipment with greater capacity, such as double-stack container cars, and redesign of these cars so they have lighter empty weights, has contributed to this trend.[Ref.18:pp.106-107]

The railroads have been losing customers to the truck industry for a long time. In the past, TOFC was able to slow that trend. Today, containers on flatcars (COFC) is demonstrating its greater intermodal versatility relative to TOFC. Table 2.1 shows that container loadings were up 8 percent, from 2,269,561 in 1990, to 2,450,026 in 1991. However, the data shows that the increase in containers did not offset the continuing decline in trailer loadings which fell 6.9 percent to 2,662,072 from 2,858,674. The decrease

TABLE 2.1. RAIL INTERMODAL TRAFFIC (UNITS IN CONTAINER LOADINGS PER YEAR)

	1990	1991	(% Change)
TOFC	2,858,674	2,662,073	(-6.9%)
COFC	2,269,561	2,450,026	(+8.0%)
	5,128,235	5,112,099	(-0.3%)

Source:[Ref.19:p.16]

in total movement was probably due to a decline in overall freight movement due to the general economic down-turn. [Ref.19:p.16]

The invention of the double-stack system should allow the railroads to regain their market share from truck longhauls. In order to accommodate double-stack containers, rail cars are designed with a depressed well so that containers can be stacked two-high within most railroad clearance limits. These wells or platforms are articulated (united or joined) in sets of five, adjacent wells being supported by one shared rail truck assembly.[Ref.3:p.6] The articulation of double-stack cars greatly improves ride quality and reduces freight damage compared to conventional flatcars. The length and weight capacity of double-stack cars has been increased to handle 48-foot containers and heavier loads. The most recent version is the "Type 3" car, capable of handling 48-foot containers in all wells with 53-foot containers on top, and equipped with 125-ton trucks to handle up to 125,000 pounds in each well.[Ref.3:p.6] In 1989 there were approximately 3,200 five-unit double-stack cars in service, or 16,000 total wells.[Ref.3:p.6]

Double-stack cars are lighter, shorter, more aerodynamic, and give a better ride, than other rail container cars. Double-stack cars provide a very good net-to-tare (cargo weight to car plus empty container weight) ratio and carry the greatest number of revenue loads for a

given train length. The result is that fuel consumption is lower due to the lower weight and labor costs are lower due to more revenue units being moved per train crew.[Ref.3:p.6] These two factors are the two major line-haul cost advantages of double-stack cars over other intermodal technologies.

E. MILITARY AND THE CONTAINER TREND

The Department of Defense has defined objectives to establish a container-oriented distribution system capable of meeting potential mobilization and deployment goals.[Ref.20:p.1] One objective is aimed at establishing containerized shipments as the preferred method of movement of military vehicles, equipment and supplies, unless cost-effectiveness or peculiar shipping requirements are an overriding factor. The DOD's objectives are not limited to the development, procurement, leasing or otherwise controlling a family of containers. The policy also does not recommend the procurement of a complete system for the mobilization and deployment requirements, but rather recommends a cooperative effort of the Military Services and the transportation industry.[Ref.20:p.1]

The purpose of DOD's containerization policy is to enable the mobilization and deployment objectives to be attained by the employment of transportation industry assets supplemented with DOD assets. DOD preference is for the use of the transportation industry's common intermodal equipment

such as freight containers and line-haul equipment. DOD furnished equipment should be intermodal equipment that fulfills unique requirements and common equipment that would be retained by the services for an extended period of time.

To meet these goals, the military services are required to develop plans and equipment requirements to meet their specific needs subject to review and approval by DOD. In order to accomplish the establishment and implementation of DOD's objectives, the Secretaries of the Army, Navy, and Air Force have been given specific missions. These missions, by Departments, are:

* Secretary of the Army. "Through the Military Traffic Management Command (MTMC), shall manage and monitor the status of intermodal surface containers in common-user service while these containers are in the Defense Transportation System."[Ref.20:p.1]

* Secretary of the Navy. "Through the Military Sealift Command (MSC), shall act as DOD agent for common-user service supporting those DOD Component requirements and capability assessments coordinated through MTMC."[Ref.20:p.1]

* Secretary of the Air Force. "Through the Military Airlift Command (MAC), shall act as the DOD agent responsible for the procurement of intermodal air containers and for the implementation of a system of airlift intermodal air containers and shelters for the Military Services."[Ref.20:p.1]

These missions provide an overall approach to the development and control of a DOD container system.

In general, the military services are to review, develop, coordinate, and carry out assigned programs, pertaining to container-oriented distribution systems. A

major requirement of the services is that a coordinated plan be developed and integrated into a container system within the services, DOD components and commercial industries. This plan would incorporate the elements that would be common for each Service as well as the unique elements for each Service.

Containerized movements generated in the sustainment phase of Operation Desert Shield, in 1990-1991, were moved by truck and rail (such as from Memphis to Charleston), and ocean intermodal service. These were primarily B ration meal shipments, which were assembled from inbound subsistence, approximately 38 containers per day. The meals were palletized and then loaded into containers (sixty 200-250 pound pallets per 40-foot container or 15,000 pounds, utilizing full cube).

The pallets used for the meal shipments were built at the depot and most were brought back in the containers to be reused. This has been found to be more cost-effective than continually having to produce new pallets.

The supply of intermodal containers was strained by the war. An estimated 1000 containers a week were moving to the Gulf area. However, few were coming back in part because, as they were emptied in the gulf area, they provided temporary storage facilities for arriving supplies not yet required by the forces.[Ref.21:p.12]

F. INTERMODAL FUTURE

The trends show that future intermodal technologies will develop by merging production and transport needs while still being responsive to customer needs. The final closing of these differences may ultimately see carriers becoming part of shippers' marketing functions and/or part of the consignees' inventory activities through contract carriage arrangements. In this situation international competitiveness may arise, not so much from the comparative transport advantage of any one country, but from the ability to integrate transport services more smoothly into production and consumption functions. To compete, carriers, agents, financial institutions, equipment suppliers and shippers will need to improve their commercial dialogues with each other, and develop new, often more cooperative strategies.[Ref.31:p.33]

In the past, the United States transportation industry has deteriorated due to our weakening transportation infrastructure and to our poor or deferred maintenance practices. We have also fallen behind our foreign competitors in capital investment, GNP growth, and our ability to compete abroad.

To maintain an efficient and effective transportation network, both internationally as well as domestically, the United States needs to rebuild its decaying infrastructure. The Surface Transportation Efficiency Act of 1991, passed by

Congress on 27 November 1991, will help in providing the congressional attention needed to foster intermodalism.[Ref.23:p.13] The Transportation Bill is based on four basic principles:

1. Intermodality: The optimum and most efficient use of our transportation resources and interconnections of all modes of transportation-highways, transit, airports, harbors and others-to improve productivity and to reduce air pollution and energy consumption.[Ref.24:p.69]

2. Flexibility: State and local decision makers should have the option of how to invest transportation resources in their areas. It should not be up to the federal government to tell the state and local officials how to invest their transportation infrastructure funds.[Ref.24:p.69]

3. Equity: Some states had legitimate complaints about their fair return from the Highway and Transit Trust Funds. To the maximum extent possible, this bill addresses these concerns.[Ref.24:p.69]

4. Financial Investment Resources: The bill provides for substantial investment in the transportation infrastructure that will pay immediate and long-term economic dividends which are absolutely essential to meet the enormous needs of our nation for road and bridge construction and rehabilitation, expanded mass-transit capacity and implementation of new technologies.[Ref.24:p.69]

This bill is expected to promote the development of a national intermodal transportation system to obtain the optimum yield of our transportation resources. It will be the focal point of domestic policy in the future and gives the hope of further intermodal growth.

III. THE DOUBLE-STACK CONCEPT

A. INTRODUCTION

Double-stack container operations has brought the intermodal industry to the point of large-scale domestic containerization. Domestic container services are routinely marketed by railroads, ocean carriers, and third parties. Thereby, giving intermodal transportation sustainability.

Several factors have helped to promote the double-stack revolution. First, there was the regulatory exemption of intermodal rail transportation, and the increased use of railroad contracts.[Ref.10:p.18] Then the Shipping Act of 1984 allowed maritime liner carriers to enter into joint services and price arrangements with railroads and motor carriers. Now liner carriers are permitted to establish through rates involving both ocean and inland movements. [Ref.18:p.242] The act also facilitated through intermodal bills of lading. Prior to that, ship companies were limited to port-to-port rate making. Finally, there was the rapid growth of containerized imports where the availability of double-stack technology was found to be the most efficient means of carrying large numbers of containers inland.[Ref.10:p.19]

These factors led to a rapid increase in the volume of international containers moving inland on double-stack

trains under contracts between railroads and ocean carriers, such as between American President Lines (an ocean carrier) and Union Pacific Railroad. The liner carriers took the initiative at the beginning of this trend (early 80's), guaranteeing annual traffic volumes and providing cars to minimize the risk to the railroads [Ref.9:p.31]. As the potential of double-stack traffic became more apparent, railroads hastened to offer contracts, supply equipment, and operate common-user trains to attract more ocean carriers. [Ref.9:p.83] By 1989, the railroad/ocean carrier relationship had become a series of individual relationships ranging from simple rate structures covering volume "tiers" to large-scale assumption of railroad intermodal marketing functions by ocean carrier affiliates.[Ref.25:pp.14-15]

Ports are involved in double-stack traffic largely as providers of facilities, but they have had, and will likely continue to have, other roles as well. In the initial period (mid 80's) of double-stack activity, ports took an active role in promoting double-stack service for their ocean-carrier clients.[Ref.26:p.35] This activity did not extend to operating trains, although some serious proposals were made. Currently, the most active port role is as the provider of on-dock facilities, where containers can be transferred between double-stack trains and the marine terminal without motor carrier drayage over city streets between the rail lines and the ports.

To get a better understanding of the roles and benefits of the double-stack system, this chapter will provide some insights on the double-stack concept and discuss its advantages and disadvantages. We will investigate the use of double-stack domestically and touch on its military logistical use.

B. BACKGROUND OF THE DOUBLE-STACK SYSTEM

1. Early Development of Double-Stack

Double-stack container services were not created by the actions of any one party. They emerged instead from a series of actions, each facilitating or broadening double-stack services in some way.

The first critical development was the design of the double-stack car itself by a team of Southern Pacific mechanical engineers under the direction of W. E. Thomford in conjunction with American Car and Foundry (ACF) Industries in 1977.[Ref.3:p.5] These cars were specifically intended to reduce linehaul costs of Southern Pacific's (SP) Sea-Land traffic in the Southern Corridor. A single-platform version was completed in 1977 and subsequent versions were produced in 1979 and 1981. These later platforms grew to three and five articulated (mechanically joined) units, with five units becoming a standard for all subsequent production.[Ref.3:p.17]

American President Lines (APL) ran its first experimental double-stack train, with Southern Pacific, from

Los Angeles to Chicago in 1983. Double-stacking was a technological improvement over the intermodal flatcars which had been in used on APL Liner-trains since 1979. APL sought to maintain and improve on the control it had achieved over inland operations with its conventional Liner-train service, and to reduce linehaul costs on that service.

Regular APL double-stack service started in 1984, and was followed by double-stack service by Sea-Land in 1985. Soon thereafter, eight rail carriers were providing services from both coasts. During 1985, there were 32 eastbound trains a week from the west coast. As of June 1988, 76 trains operated each week between 20 city-pairs. The 1990 container portion of the U.S. intermodal market was 45%, providing a large potential market for double-stack services. [Ref.27:p.24]

Despite being occasionally identified as the operators of double-stack trains, ocean carriers actually only own railcars and there are only three ocean carriers who actually acquired double-stack cars (APL, Sea-Land, and Maersk). Railroads acquired a few cars (either leased or purchased), but the vast majority of double-stack cars has been provided by Trailer Train (now known as TTX). Trailer Train Company was incorporated by the Pennsylvania Railroad and the Norfolk and Western Railway in 1955. Now owned by 14 railroads and rail systems, Trailer Train provides a fleet of over 44,000 intermodal cars.[Ref.28]

Trailer Train's decision to create a double-stack car fleet was a major factor in the double-stack momentum. Once Trailer Train began leasing double-stack cars, it was no longer necessary for either ocean carriers or railroads to commit capital to the new service. Until this ability was recently curtailed as a condition of continuing anti-trust immunity, Trailer Train could assign a group of double-stack cars to a specific railroad for a period of several years for use by a specific ocean carrier. By permitting ocean carriers and railroads to start services without the capital outlay for rail cars, Trailer Train dramatically reduced the barriers to double-stack service and diminished the risks borne by individual carriers. This allowed expansion of double-stack services beyond the dedicated trains of major ocean carriers. In fact, with few exceptions, the ocean carriers who purchased or leased cars for their initial trains turned to the use of Trailer Train cars for subsequent expansion. Trailer Train thereafter committed heavily to double-stack technology. Further development of domestic double-stack services is likely to rely on Trailer Train and/or other firms to supply and maintain pools of double-stack cars.

2. Developments After Regulatory Reform

As these developments were occurring, railroad regulation was being substantially reduced (between 1976 and 1981), permitting railroads to conduct intermodal business

in a much freer environment. In 1976, Congress passed the Railroad Revitalization and Regulatory Reform (4R) Act, which allowed the Interstate Commerce Commission (ICC)[2] to exempt certain traffic under limited circumstances. [Ref.18:p.111] The 4R Act paved the way for more extensive regulatory reform. The major progress in railroad deregulation came with the passage of the Staggers Rail Act of 1980, which gave the railroads considerable latitude in determining and modifying rates without the ICC's interference, and backed up an earlier ICC ruling on contracts by permitting contract carriage by rail common carriers. The ICC then exempted some TOFC/COFC service from rate regulation in 1981 and eliminated all remaining TOFC/COFC rate regulation in 1987. The railroads' ability to make contracts with their customers proved to be an important element in the success of the innovative intermodal services developed during the 1980's.[Ref.29:p.103]

The rails' role in the double-stack industry must be viewed in the context of overall intermodal growth and a change in the way intermodal traffic has been conducted and perceived. All of the early double-stack trains were

[2]The role of the ICC in the economic operations of carriers has been greatly reduced since passage of the Motor and Rail Deregulation Act in 1980. As a consequence of market place control and reduced funding for ICC operations, the ICC now primarily considers transportation issues of national concern.[Ref.18:p.53]

dedicated services. Each ocean carrier had a set of double-stack cars, owned, leased, or assigned by Trailer Train for its use. Each service effectively operated as a unit train, although the sets of cars were broken up and rearranged from time to time. Thus, for the first year or so, double-stack trains were viewed as unit trains, and operationally distinct from other railroad trains. The introduction of common-user services by several railroads in 1985 and 1986, and the development of multi-destination trains, quickly ended any such distinction.[Ref.29:pp.107-109] Railroads now mix double-stack cars with other cars to achieve the desired capacity and service frequency.

The introduction of double-stack service coincided with strong growth of import cargoes in the trans-pacific trade, which created a heavy eastbound imbalance. Based on Bureau of the Census data, an estimated 1.4 million Twenty-Equivalent-Units (TEU: 8x8x20-foot intermodal container) of imports passed through the West Coast ports in 1984 compared with only 0.9 million TEU of exports, an imbalance of 1.6:1. The imbalance grew to 1.9:1 in 1985 and 2:1 in 1986. Since APL initially leased or owned its double-stack cars and had full responsibility to fill the cars in both directions, it had significant incentive to develop additional cargoes to fill westbound containers. In 1985,

APL acquired a shippers' agent, National Piggyback Services[3] and a distribution service, Intermodal Brokerage Services. It then formed American President Intermodal to oversee its double-stack services and had APDS solicit domestic freight and APL solicit international cargo.[Ref.30:p.40]

While Sea-Land and Maersk also purchased double-stack cars, few ocean carriers made the capital commitment of APL. Most, however, recognized the need to provide double-stack services, and some recognized the opportunity to compete for domestic traffic. The roles played by ocean and rail carriers thus became less clearly defined. Ocean carriers have taken responsibility for a larger portion of the transportation chain from shipper to consignee, and a greater portion of the risks and revenues.

Double stacking of intermodal containers is just one competitive advance in a deregulated industry, where advances are occurring with increasing frequency and effect. However, the double-stack network holds the highest potential of being able to interconnect the total transportation system whether it be on the ocean, on land, or in the air.

C. ADVANTAGES OF THE DOUBLE-STACK SYSTEM

When asked in a "Traffic Management's" survey about preference of double-stacked containers over conventional

[3]Renamed American President Distribution Services or APDS.

TOFC, 58% had no preference. However, the subscribers who did have a preference chose double-stack over TOFC 3 to 1 (3:1). (See Figure 3.1) This is due to the many advantages of double-stack.[Ref.31:p.34] The double-stack system reduces train lengths and reduces capital costs per payload ton carried. Train length is important on single-track mainlines where passing sidings limit train length and when labor contracts are based on train length. Double-stack equipment doubled the number of containers per train, thus cutting train crew labor cost per container in half. The reduction in capital costs arises from the fact that containers, unlike trailers, have no expensive running gear or chassis that must be carried around. Each double-stack car can carry the same payload as five single-level flat cars for about 75 percent of the capital costs, because the articulated design permits elimination of four railroad trucks and four pairs of couplers and air hoses.[Ref.28]

A standard railroad flatcar, with two 45-foot containers, has a total tare weight of about 83,800 pounds while the stack-train platform, with two stacked (one 45-foot and one 48-foot) containers, weighs about 53,450 pounds, a savings in tare weight of 30,350 pounds. Net payload to tare ratio is 1.38 for standard type COFC service versus 1.97 for double-stack.[Ref.3:p.6] (See Table 3.1) This reduction in weight translates into a 40 percent savings in fuel costs. The advantages of double-stack is

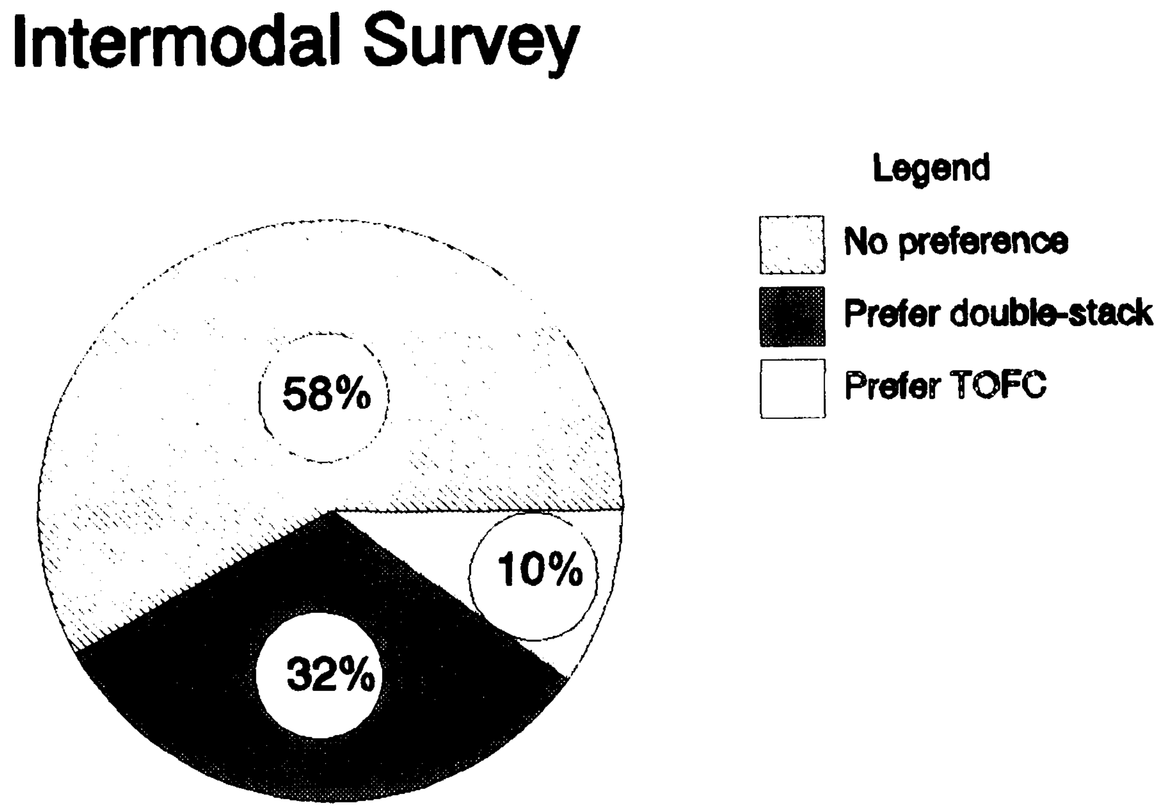


Figure 3.1. Intermodal Survey on Preference of Double-Stacked Containers vs. Conventional TOFC. (Units in % of 500 Total Surveyed.)

Source: [Ref.31:p.34]

TABLE 3.1. WEIGHT CAPACITY COMPARISONS

Car Type	Net Weight Capacity (lbs.)	Total Tare Weight (lbs.)	Coupled Length (ft.)	Net/ Tare	Net Lbs. Per Foot
Double-Stack IBC 5 45' Containers 5 48' Containers	526,800	267,250	289-8	1.97	1,819
Standard TOFC 2 45' Vans	104,000	93,600	93-8	1.11	1,110
Standard COFC 2 45' Containers	116,000	83,800	94-8	1.38	1,225
RoadRailer Mark V	48,800	16,200	48-0	2.01	1,017

Source: [Ref. 3:p.6]

also evident in the "Net pounds Per Foot" data, in Table 3.1, where cargo density is most efficient with double-stack.

Total cost savings for the line-haul portion of the train movement have been estimated as high as 40 percent by the Association of American Railroads. Other estimates, however, indicate total cost savings of through movement when compared to conventional TOFC is about 20 to 25 percent.[Ref.32:p.73] The lower figure reflects the higher drayage expense caused by the fact that double-stack terminals are fewer in number and farther apart.

An important cost savings and marketing advantage for double-stack lies with low loss and damage claims. The platform articulation eliminates some couplers and associated gear. This has reduced slack action, or the running in and out of couplers that magnifies the forces of inertia and creates damage to cargo. Double-stack operations are also rarely switched when loaded, thus further reducing rate of cargo damage. Situations where freight cars bump into one another as they are classified and pushed over the hump (in railroad hump yards) are, as a result, usually avoided.

Double-stack cars are also a deterrent to theft because the container doors are difficult, if not impossible to open while in transit. Since loss and damage is a strong concern

of shippers, double-stacks' loss and damage experience is a significant marketing advantage.

D. DISADVANTAGES OF THE DOUBLE-STACK SYSTEM

The disadvantages of double-stack are the large volumes of freight required to make it viable and high terminal costs. As a result, double-stack trains can only operate economically in long-haul service between high-volume terminals, where high terminal costs can be spread over more miles and containers, thus reducing terminal costs relative to total revenues.[Ref.33:p.16] The requirement for high volume, long-haul lines limits the markets where double-stack can operate successfully.

As time progresses, volume, management experience, and new technology may shorten the break even distance for double-stack. Given careful asset management and reasonably high volumes, it has been suggested that double-stack can eventually operate in corridors as short as 500 miles.[Ref.33:p.19]

Double-stack trains also need high overhead clearances (a minimum of 20 feet, 6 inches, from the top of the rail, is required to accommodate two stacked containers). This rules out many potential routes where restrictive tunnel and bridge clearances are encountered. However, low line-haul costs have made it economical to increase the clearances and thus open up many of these routes.[Ref.10:p.18]

In addition to the need to improve bridge and tunnel clearances, there are questions about improvements needed in roadbeds, rolling stock, and terminal facilities. Terminal facilities require considerable improvement in many localities in terms of space and handling equipment.

Rail carriers have mixed feelings about double-stack train operations. Negatives reactions, however, are not being expressed too loudly in the face of the headlong rush to compete in double-stack markets.

E. DOMESTIC USE OF THE DOUBLE-STACK SYSTEM

The introduction of double-stack equipment in the 1980's for marine containers rekindled interest in the concept of domestic containerization. This also occurred during a period when the U.S. dollar was very strong and imports (particularly from the Pacific Rim) far outweighed exports. Many containers would have returned empty to West Coast ports if it were not for domestic cargo from the East Coast and Midwest filling the backhaul. APL, for example, was able to generate substantial amounts of domestic backhaul freight. Because of available backhaul capability and low double-stack costs, domestic containerization become very competitive and siphoned away westbound traffic from both piggyback and highway traffic.[Ref.34:p.61]

F. MILITARY USE OF THE DOUBLE-STACK SYSTEM

The initiation of Operation Desert Shield tested our ability to provide quick and smooth transportation for the

massive volumes of cargo needed to be delivered. This was an opportunity to test our intermodal capabilities.

Military volumes rose from 250-300 Forty Equivalent Units (FEU: 8x8x40-foot intermodal container) in the early weeks of Desert Storm, to 3,300 FEUs per week in early February 1991. In February, APLs military volume alone, was close to 1,000 FEUs per week.[Ref.36:p.64] "APL's domestic transportation affiliate operated cross-country, double-stack container trains as part of an integrated transportation system that also included ships, truck and computerized information systems."[Ref.36:p.64] Intermodal companies such as APL were concerned of the possibility that "The government could influence schedules or even commandeer double-stack trains to rapidly shuttle cargo to seaports."[Ref.35:p.34] However, since many military transportation planners were skeptical of the applicability of containerization, many items that were containerizable were not carried in containers.[Ref.36:p.66] In most cases old transportation techniques superseded DOD Directive No. 4500.37 (containerization policy) for convenience sake.

IV. GROWTH IN DOUBLE-STACK NETWORK

A. INTRODUCTION

This chapter will investigate the growth of the double-stack network and its effect on the trucking industry. We will look at the current double-stack network and then discuss the growth in this network. The question of whether double-stack can actually compete against truck services will be answered and the cost to the rail industry to maintain or surpass its present competitive standing, with trucking, will be considered. We will then explore the items that may effect double-stacks' future growth.

B. THE DOUBLE-STACK NETWORK

The double-stack network is shown in Figure 4.1. The combination of routes and hubs shown in this figure provides very extensive national coverage, enabling double-stack trains to serve all major U.S. markets. As Figure 4.1 illustrates, double-stack operations have begun to resemble a network of interlocking movements rather than a collection of unrelated unit trains. This development has greatly assisted double-stack operators in competing with trucks, because it has created the traffic density which permits a service frequency needed to attract the business of demanding customers. The development of a network has also

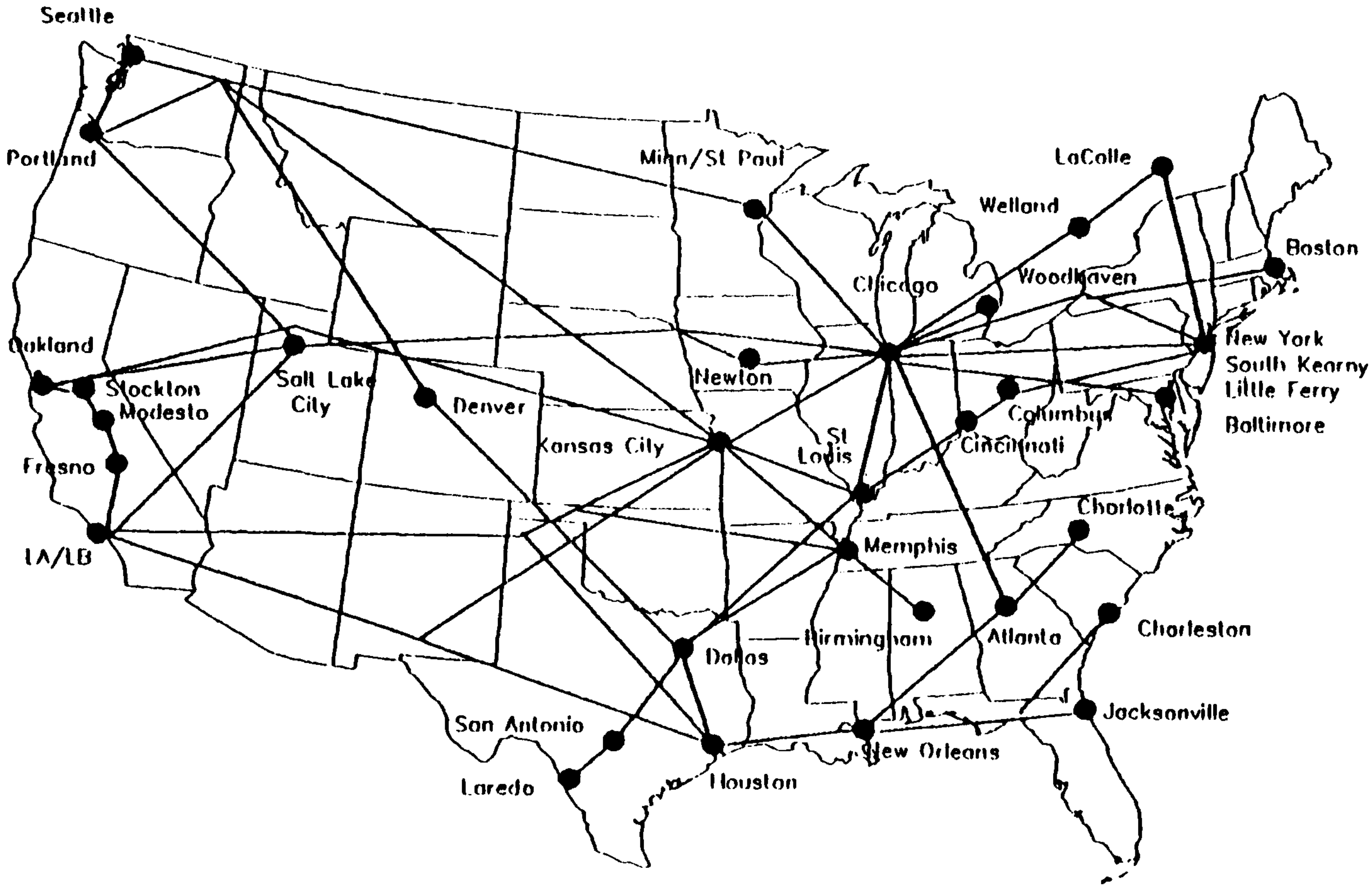


Figure 4.1. 1990 Double-Stack Network
Source: [Ref.10]

extended double-stack service to several hubs that could not yet support dedicated hub-to-hub unit trains.

C. GROWTH IN THE NETWORK

Intermodal rail traffic grew dramatically in the 1980's as shown by Figure 4.2 (especially from 1982-1987 during which the average annual growth rate was approximately 12 percent). The growing share of railroad traffic and revenues demanded a larger share of management attention.

The dedicated "unit" trains of APL and Sea-Land set the pattern for early double-stack operations. The introduction of "common-user" service by Burlington Northern (BN) in 1985 led to far greater flexibility in double-stack operations. As Table 4.1 shows, in 1983, the domestic intermodal rail fleet totalled 109,900 spaces, including 109,000 spaces on conventional cars, 200 spaces on third generation TOFC cars, 400 on double-stack cars and 300 RoadRailer spaces. By 1989, the number of spaces on conventional cars was down to 79,000 while the double-stack fleet rose to 30,000 spaces.[Ref.33:p.17]

More than 100 trains depart the West Coast each week with double-stack traffic. Configurations include single-customer unit trains, regularly scheduled common-user trains serving multiple customers, combined double-stack and conventional intermodal trains and blocks of double-stack cars moving on intermodal or manifest freight trains.[Ref.33:p.18]

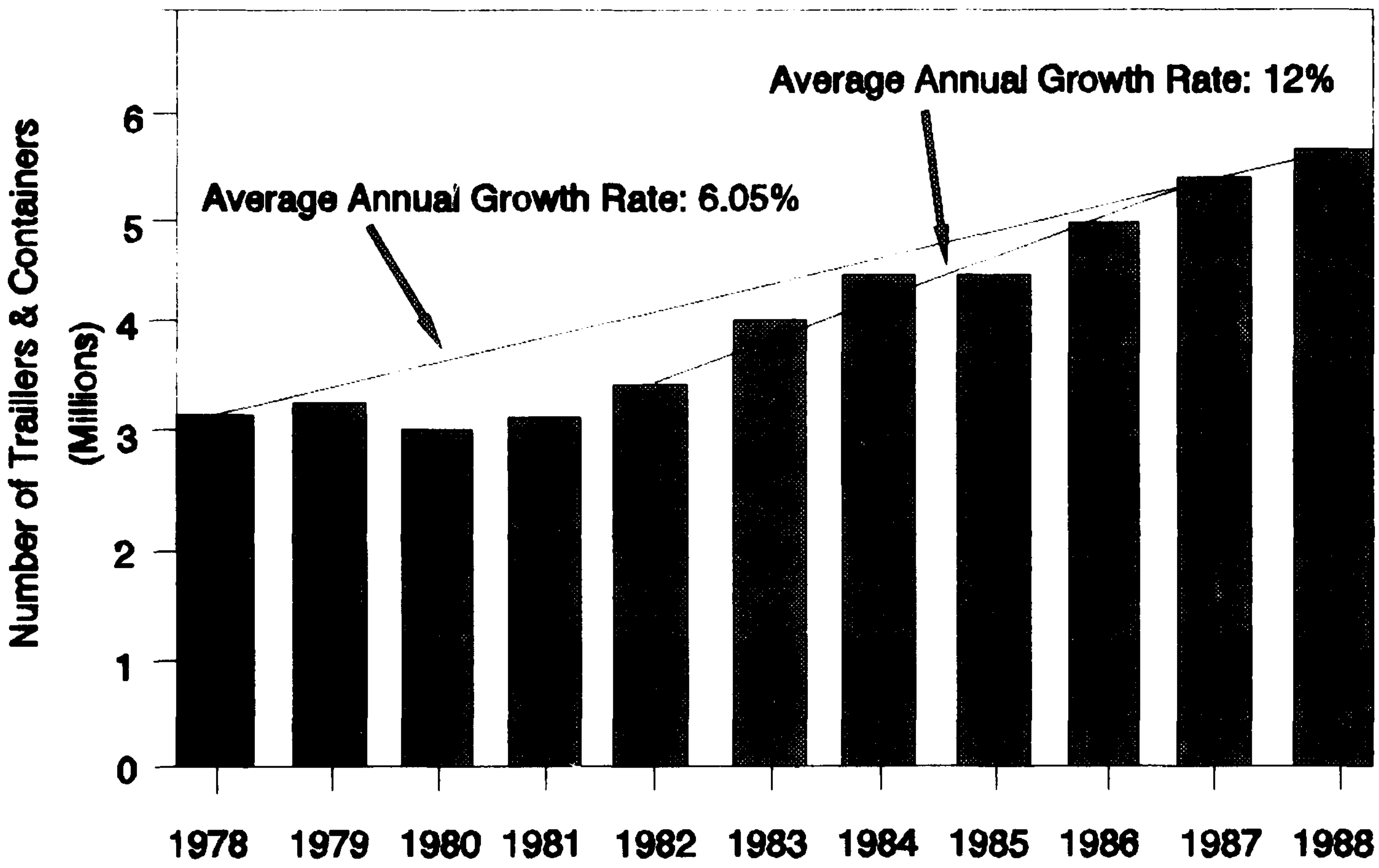


Figure 4.2. Rail Intermodal Volume 1978-1988

Source: [Ref.42]

TABLE 4.1. INTERMODAL FLEET TRAILER OR CONTAINERS FROM 1983-1989

Year	Total Spaces *	Conventional Equipment	3rd Gen. TOFC	Road-Railers	Double-Stacks
1983	109,900	109,000	200	300	400
1984	112,000	109,000	700	300	2,000
1985	119,200	109,000	2,900	300	7,000
1986	118,400	102,000	3,100	300	13,000
1987	117,200	93,000	4,800	1,400	18,000
1988	120,100	88,000	5,800	2,300	24,000
1989	120,300	79,000	9,000	2,300	30,000

* Units are trailer or containers spaces or slots.

Source: [Ref.33:p.17]

Today's container traffic is still overwhelmingly international, and rail container flows are concentrated in traffic lanes connecting major maritime container ports with major inland intermodal hubs. Domestic container movements accounted for only 9 percent of rail intermodal traffic in 1989, but this market is seen as having excellent growth potential.[Ref.26:p.36]

D. DOUBLE-STACK VERSUS TRUCKS

Double-stack container systems have line-haul cost advantages over other modes of transportation and may displace those modes.[Ref.16:pp.252-253] However, unless double-stack service is fully competitive with truckload service in a given market, domestic double-stack traffic will remain subject to erosion by motor carrier competition in that market.

It has been determined that door-to door domestic double-stack linehauls must be at least 725 miles to be competitive with the operating costs of truckload carriers.[Ref.33:p19] In longer corridors, as will be shown in chapter VI, double-stack has a line-haul cost advantage. Service frequency and sufficient traffic volumes are also critical to domestic double stack viabilty. Major domestic corridors require six-day-per-week service (between the end points), while five-day-a-week service is adequate for origination and terminations at intermediate points with lower traffic volumes.[Ref.33:p.17] A five-day-per-week

schedule would allow double-stack service to compete effectively for much, but not all, common-carrier truckload freight.

There are several obstacles double-stack service must overcome to reach its full potential. While some are technical, the most serious ones involve marketing, management and organization. In particular, the industry must provide and market a reliable, high-quality, door-to-door service. To capture a larger traffic share, railroads must provide door-to-door service that is competitive on both price and quality with truck service. The challenge encompasses technology, line-haul operations, terminal operations, marketing, sales, customer service, management and organization. If the intermodal industry can overcome the obstacles to door-to-door service quality in each of those areas, double-stack container systems can compete successfully with trucks and other intermodal systems and sustain a larger market share than intermodal transportation has yet earned.[Ref.33:p.18]

One way of organizing and managing door-to-door, double-stack service is to bring some or all of the functions under the ownership or control of one multimodal firm. There are many approaches to multimodal ownership or control, and ownership of assets or operations in more than one mode does not always yield integrated intermodal transportation. The goal of multimodal firms engaged in intermodal

transportation is improved service coordination and better asset utilization. [Ref.33:p.18]

A possible snag in the development of domestic double-stack services is a proposal to allow larger trucks on U.S. highways, thereby reducing truckload costs. Each 1 cent per mile drop in truck costs would increase the minimum length of truck-competitive double-stack hauls 11 miles beyond the 725 miles competitive mark previously mentioned. If truck size and weight limits are relaxed to allow widespread use of twin 48-foot trailers, truckload costs would drop about 30 percent.[Ref.33:p.17]

On the other hand, rising fuel prices or higher fuel taxes could increase truckload costs and divert existing truckload traffic to rail. A 25-cent fuel tax increase and a 4-cent price increase would raise truck operating costs by 5.18 cents per mile and reduce the minimum truck-competitive double-stack haul to 670 miles.[Ref.33:pp.16-17]

E. FUTURE GROWTH

A large gap still exists between what is possible in double-stack operations and what is reliably achieved, despite improved transit times and damage prevention. The biggest shortcoming in current double-stack and other intermodal operations is the lack of sensitivity to market needs, particularly in door-to-door reliability. [Ref.4:pp.17-18]

Double-stack transportation has developed despite

fragmentation, yet it cannot attain its ultimate potential unless the necessary functions are successfully integrated in the eyes of the customer.

V. DOUBLE-STACK RELATIONSHIPS

A. INTRODUCTION

The growth of domestic containerization raises many interrelationship issues. The question of compatibility between international and domestic container-based intermodal transportation will determine the true value of containerization as a convenient intermodal medium to transfer cargo safely, quickly and economically. This chapter is concerned with the relationships between international and domestic containerization. It focuses on physical, operational, and port relationships which affect the long term capabilities of the double-stack system.

B. PHYSICAL RELATIONSHIPS

1. Relationships in Containre Sizes

There has been a good deal of concern over the intermingling of domestic and international containers of different sizes. International containers are all marine containers and currently come in 20-foot, 40-foot, and 45-foot lengths. These containers are the same width: eight feet, their heights range from 8 feet to 9 feet 6 inches. Containers built especially for domestic service come in 45-foot, 48-foot, and 53-foot lengths, with the 48-foot length being predominant.[Ref.42:p.23] Burlington Northern (BN) has introduced a small number of 24-foot domestic flatrack

containers[2], primarily for forest products. Newer domestic containers are 9 feet 6 inches high, and 102 inches (8 feet 6 inches) wide.

Among the international sizes, the 40-foot container predominates on international routes involving the U.S. (On non-U.S. routes the 20-foot container predominates.) [Ref.9:p.122] For example, forty-foot containers account for 71 percent of the containers passing through Southern California. The mix varies only slightly by direction. In Southern California, 40-foot containers accounted for 69 percent of the imports and 73 percent of the exports.[Ref.28]

The mix of international containers is changing, although slowly, toward the larger 45-foot containers [Ref.28]. Since there are roughly 5.5 million Twenty Equivalent Units (TEU: equivalent units to a 8x8x20-foot container) in service worldwide, new purchases make only a marginal difference in the fleet.

The major purchasers of new 45-foot containers, APL, Maersk, and Sea-Land, are also heavy users of double-stack, causing these new containers to show up in double-stack operations more often than their overall prevalence would suggest. Industry estimates indicate that over 40,000 such

[2]Flatrack containers are containers without ceilings and sides. Corner posts or sidings are used to keep cargo bundled.

containers will be in service by the end of 1992,[Ref.28] including additions to the leasing company fleets.

The marine fleet is also getting taller, as the number of "high cube" containers (9 feet or 9 feet 6 inches) grows. By the end of 1992, high cube containers are expected to account for roughly 9 percent of the world fleet.[Ref.28] The new 45-foot containers are normally high-cube containers and are being deployed most rapidly by the steamship companies heavily involved in double-stack services, and hence are probably more prevalent in U.S. intermodal routes.

Ocean carriers do not presently use 48-foot or larger containers in regular international service, nor do they use containers with outside widths greater than 8 feet. The ability of ocean carriers to use larger containers is limited by the configuration of cellular containerships which are ships that carry only containerized cargo.

The fleet of domestic containers has grown rapidly, but it is still very small compared to the volume of marine containers moving inland. The vast majority of domestic containers are 48 feet long, 8 feet 6 inches wide (120 inches), and 9 feet 6 inches high. The so-called "48 x 102" size also accounts for virtually all domestic containers on order (except for the small number of 24-foot flatrack containers ordered by BN).[Ref.37:p.49]

Since domestic containers are not meant for international shipments, there is no requirement to build them to international standards. They do, however, have standard corner castings located at 40-foot positions to permit stacking on marine containers of the same width. When containers are stacked, Inter-Box-Connectors (IBC)[3] are used to connect the containers at those corner castings. A 45-foot, 48-foot, or 53-foot container (above a 48-foot well) can be stacked on a 40-foot or larger container and linked by IBC's positioned on the 40-foot spacing.

The International Standards Organization (ISO) is considering a new standard for not only longer, but wider marine containers, the so-called "wide body" containers. The proposed 49-foot ISO container has a width of 8 feet 6 inches and a height of 9 feet 6 inches.[Ref.9:p.173] If a new "wide-body" container standard were able to provide castings to match 40-foot containers (as has been done with other large containers), a 49-foot, 102-inch marine container could be handled on the top tier of double-stack cars. Subsequent orders of double-stack equipment would likely provide for any ISO standard that stack-train customers plan to use. There is, however, strong opposition to the adoption of the "wide body" standard in the U.S. from

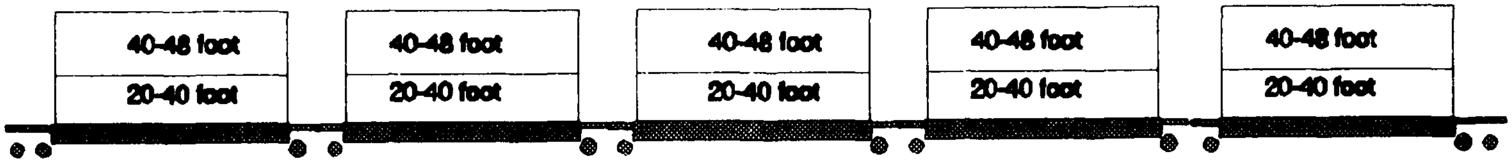
[3]not to be confused with Intermediate Bulk Containers, these containers are filled at the top, and emptied from the bottom with the aid of gravity.

commercial interests. Whether it will be adopted as an ISO standard is problematic at present.

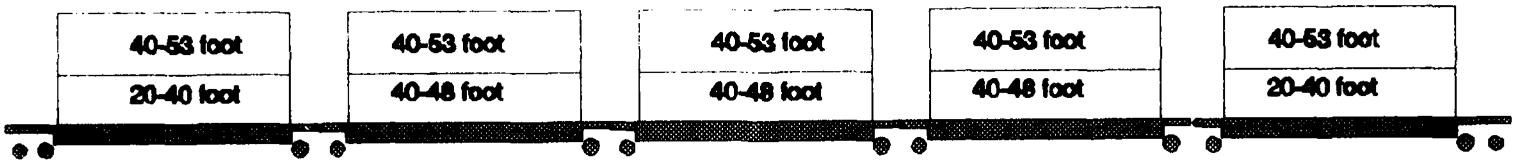
2. Relationship Between Containers and Railcars

In order to integrate domestic and marine containers into a common intermodal network, two physical attributes of domestic containers must be accommodated during movement: size (length and width), and strength (stacking height). The size interrelationship has been addressed in the double-stack arena by increasing the well length on new cars to accommodate larger containers on the bottom tier, and by installing compatible castings with 40-foot spacing on containers that exceed the traditional 40-foot length.

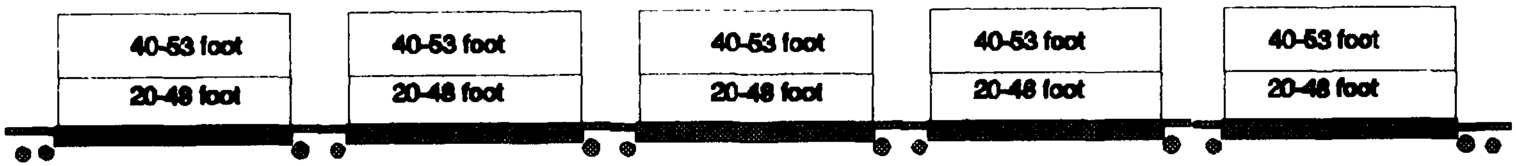
In response to the proliferation in container lengths, builders are providing new double-stack cars that can handle container lengths up to 48 feet in the wells [Ref.38:p.54]. Figure 5.1 shows the three types of double-stack cars consisting of five articulated (mechanically connected) platforms. The Type 2 and Type 3 platforms can accommodate up to 48-foot containers in the wells and 40-foot to 53-foot containers on the top tier connected with IBC's. The Type 2 cars are slightly shorter due to the two end platforms being designed to carry only up to 40-foot containers on its well. Although many existing cars have some loading restrictions, the loading problem will be reduced as the fleet expands. The problems of loading a



Type 1 Double-stack car: Well accommodates up to 40-foot containers with top container up to 48-foot.



Type 2 car: End wells accommodates 40-foot, 45-foot for inner wells; top container up to 53-foot



Type 3 car: Up to 48-foot containers on all wells with top container up to 53-foot.

Figure 5.1. Recent 125-Ton IBC Double-Stack Car Types

Note: Where 20-foot Is Indicated , Two 20-foot containers are placed

Source: [Ref.3]

mixed fleet of double-stacks will be no worse than loading the existing and more varied mix of TOFC/COFC cars.

The current or anticipated mix of international and domestic container sizes will not create significant physical compatibility problems for double-stacks as long as new, larger containers have attachment points in compatible locations. Non-bulkhead type double-stack cars (using IBCs) can accept virtually any combination of containers, making terminal stacking differences minimal and avoidable. The mix of container sizes and types coming through the rail terminal gate will continue to command management and clerical attention, regardless of whether the containers are domestic or international, but it would more accurately be regarded as an inconvenience to be dealt with rather than a stumbling block to development of a double-stack network.

C. OPERATIONAL RELATIONSHIPS

1. Relationships with Cargo Flow

The demand for rail carriage of international containers adds significant new cargo volumes, and thus trains, to the U.S. rail corridors; particularly the major mainline routes that connect West Coast ports with Midwest and Eastern intermodal hubs. Mini-land-bridge[4] traffic between Los Angeles and New York is new cargo for the

[4]A joint water, rail or truck container move on a single Bill of Lading for a through route from a foreign port to a U.S. port destination through an intermediate U.S. port where the leg between the two U.S. ports is a land movement (or the reverse).

railroads, having been moved previously by the all water route through the Panama Canal (prior to 1972). Micro-land-bridge[5] traffic between Los Angeles and Chicago is partially new; a relatively short New York to Chicago movement from the east coast is now supplanted by a longer Los Angeles to Chicago move from the west coast (generally involving different railroad carriers).

The top part of Table 5.1 shows projected year 2000 import and total international container flows, in thousands of Forty Equivalent Units (FEU: equivalent units to 40-foot containers; 2 TEUs=1 FEU), between eight port regions and eight destination regions (Southern and Northern California being combined into the one California destination region).

The lower part of Table 5.1 shows projected year 2000 export in FEU's. The two right-hand columns are percentages which sum up to 100% and present the likely intermodal share (i.e., those containers destined outside the local port areas) and the local share (i.e., those cargoes consumed within the local region, or distributed by the consignees outside the local region independently of the ocean carriers). Table 5.1 incorporates projected annual growth rates of 4 percent for imports and 6 percent for exports, derived from data from Bureau of the Census and

[5]Same as Mini-land-bridge, except, that it is to or from an inland U.S. city (instead of another maritime U.S. Port).

TABLE 5.1. PROJECTED ANNUAL INTERNATIONAL IMPORT AND EXPORT CARGO FLOWS BY RAIL CORRIDOR FOR THE YEAR 2000 (UNITS IN 1,000 FEU)

Destination Region for Imports

Port Region	California Total	Pacific Northwest	Mountain States	Upper Midwest	Lower Midwest & Gulf	Northeast	Mid-Atlantic	Southeast	Total	Likely Intermodal Share	Local Share
So. California	441	11	15	167	101	312	45	33	1.125	60.8%	39.2%
No. California	113	4	6	13	5	54	3	4	202	44.1	55.9
Pacific Northwest	44	50	7	101	17	174	15	7	415	88.0	12.0
Upper M.W.	0	0	0	1	0	0	0	0	1	0.0	100.0
Lower M.W. & Gulf	7	1	3	10	35	30	2	14	102	70.6	29.4
Northeast	40	4	2	89	16	839	27	18	1,035	18.9	81.1
Mid-Atlantic	13	4	5	82	8	105	96	26	309	66.0	34.0
Southeast	15	1	1	19	9	85	25	146	301	51.5	48.5
	673	75	39	425	191	1,599	213	248	3,490		

Origin Region for Exports

Port Region	California Total	Pacific Northwest	Mountain States	Upper Midwest	Lower Midwest & Gulf	Northeast	Mid-Atlantic	Southeast	Total	Likely Intermodal Share	Local Share
So. California	327	8	14	65	116	17	27	32	606	46.0%	54.0%
No. California	225	6	8	18	50	5	6	14	334	32.6	67.4
Pacific Northwest	8	392	53	51	20	13	17	9	563	30.4	69.6
Upper M.W.	0	0	0	7	1	0	0	0	8	12.5	87.5
Lower M.W. & Gulf	27	2	22	22	391	14	21	176	675	42.1	57.9
Northeast	4	4	1	29	7	24	278	96	437	36.4	63.6
Mid-Atlantic	2	0	6	73	6	286	38	5	430	31.2	68.8
Southeast	3	0	1	13	20	14	53	252	356	29.2	70.8
	596	412	105	278	611	383	440	584	3,409		

Source: [Ref.39]

Bilateral World Trade Forecast. (See Appendix A for raw data.)

Import traffic on the four top intermodal corridors show significant projected volumes in the next decade: Southern California, to 1,125,000 FEU; Pacific Northwest, to 415,000 FEU; Mid-Atlantic, to 309,000; and Northeast, to 1,035,000. The rail corridors with the greatest total annual demand are expected to be eastbound from Southern California and the Pacific Northwest, westbound and southbound from the Northeast, and northbound and westbound from the Mid-Atlantic ports.

2. Relationships with Competition

Perhaps the most important change is the growing inland presence of ocean carrier subsidiaries and multimodal companies. Formation of intermodal transportation companies has blurred traditional demarcations. Today, a railroad's major customer on one intermodal rail corridor may be one of that railroad's bigger competitors on another intermodal rail corridor. For example, an ocean liner could be a railroad's major customer on one intermodal rail corridor but could be competing directly with the railroad on another corridor by providing backhaul freight service, and thereby competing for customers. [Ref.43:p.26]

The proliferation of intermodal transportation companies has exacerbated this "competitor or customer" problem for the railroads. At least five steamship lines

have U.S. subsidiaries that can compete with the railroads. The issue of commercial compatibility is less an issue of the type of cargo (domestic versus international) than of the complex interaction of railroads, intermodal transportation companies, and third-party vendors. This is not a new problem: it began with the first shippers' agent who tendered a TOFC trailer that the railroad could have solicited directly. The competition for the same market has since gone in opposite directions; some railroads have given up direct solicitation to work exclusively with third party vendors, while other railroads have started direct sales efforts.[Ref.33:p.19]

3. Relationships with Backhaul

Once APL and Union Pacific started regular double-stack operations in 1984, other ocean carriers and other railroads teamed up for double-stack traffic with varying degrees of enthusiasm. One critical issue for both ocean carriers and railroads was backhaul solicitation. [Ref.39:p.55] As mentioned in chapter III, double-stack services started during a period of strong import imbalances, leaving a large volume of containers to be returned empty unless westbound backhaul freight could be found. If westbound backhaul freight could be found then the ocean carriers would be competing directly with the railroad industry by taking away some of their customers.

If the railroads were to attempt large scale retail marketing of domestic container service, there could have been a serious conflict with the backhaul marketing of their ocean carrier clients to domestic third parties. Railroads would then need to choose between backhauls of the ocean carrier (steady customers) and high revenue third party freight. There are, however, mitigating factors. Railroad plans for retail marketing of domestic container services directly to the general public, shippers and receivers, is extremely limited. Many railroads have only marketed intermodal services directly to the largest industrial customers. Marketing domestic container services to these customers will not disrupt existing relationships with ocean carriers.

Retail marketing of domestic container services will remain in the hands of third parties for the immediate future.[Ref.31:p.34] Ocean carrier and multimodal subsidiaries will figure prominently in that third-party activity.

D. PORT RELATIONSHIPS

1. Dock and Rail Relationships

Until very recently, virtually all double-stack services originated or terminated at port cities, and were operated primarily to serve international traffic. The growing volume of domestic traffic carried by those services and the prospect of extensive domestic services have led to

some concern over the handling of international and domestic containers in port-area facilities. The development of on-dock rail facilities prompts even stronger concern that such facilities could be congested by an influx of domestic containers. Congestion on port-area highways and streets is also a matter for concern, particularly in Southern California.[Ref.48]

The compatibility of domestic and international containers at ports is an issue because of the diverse distribution requirements of the two container services. Railyards serving domestic shippers and consignees are not usually adjacent to the port. Domestic container traffic between the railyard and the domestic customers doesn't coincide with the international container flow between the port and destination point (railyard or customers in the local port regions) of the containers. If domestic containers arrive at the port (i.e., at an on-dock or near-dock facility), their volume, while waiting to be picked up, would increase congestion at the port. This would increase delivery time to the domestic consignees, and thereby increase transportation costs to the domestic consignees or shippers.

As earlier chapters of this study have established, there are three competitive sources of traffic which could benefit from conversion to domestic container service: rail TOFC, other rail (traditional boxcar) traffic, and truck

traffic. Existing rail TOFC traffic will most likely be the largest short-term source with relatively less boxcar traffic being converted. Truck traffic will take longer to convert. The immediate effect on most rail facilities would be conversion from trailers to containers, rather than an influx of new traffic.

Few intermodal yards, away from ports, are facing capacity constraints at present, and those that do are being expanded. There seems little risk of a short-term congestion problem so severe that it would impede the growth of either international or domestic double-stack services. On-dock facilities cannot be expanded significantly (in most cases) to provide extra facilities for conversions without impinging on land required for marine terminal operations. [Ref.40:pp.22-25] Moreover, on-dock facilities are usually built with port funds to provide efficient, expeditious rail service for ocean carriers' international containers. An influx of domestic containers might defeat the purpose of on-dock facilities. However, many existing rail intermodal yards that handle trailer traffic, and also service ports, believe that conversion from trailers to containers would not add traffic.[Ref.48] The long-term outlook for facilities depends on profitability. If domestic double-stack service is profitable, railroads can and will invest in the necessary facilities.

2. Port Impact

It appears that the impact of domestic container traffic on port facilities will be minimal. The appearance of port congestion from domestic boxes has been raised, but this study has found no reports of actual port congestion from domestic container traffic. Since ocean carriers, ports, railroads, marine terminal operators, and customers all have incentives to keep domestic containers out of the ports wherever congestion is likely, any influx of domestic containers in port facilities is likely to be small and sporadic unless local conditions encourage such routing practices.

The operational concern is how international containers can be brought to the marine terminals from mixed international and domestic double-stack trains. Where containers are drayed to the port, there is no problem in sorting containers (other than occasional mixups). Where containers are brought by rail to on-dock terminals, railroads and their customers will have to cooperate in loading and routing trains to facilitate the separation of those cars bound for the on-dock yard.

Where there is only one intermodal yard in a city, the routing question is moot, the issue becomes the adequacy of that facility to handle both kinds of traffic. Where there is a choice of railroad facilities, the railroad is most likely to segregate traffic by handling type (i.e.,

trailers versus containers).[Ref.28] Where substantial amounts of trailer traffic have been converted to containers, the railroad would more likely convert the trailer yard or add container-handling capability, rather than allow one facility to go under-used while the other is overburdened. Railroads have demonstrated their willingness to expand and change facilities as intermodal traffic itself expands and changes.[Ref.28] For example, SP plans to expand the Intermodal Container Transfer Facility (ICTF) in Los Angeles.[Ref.9:pp.184-185]

With railroad-owned facilities in the same area, domestic shippers would have every reason to avoid costly trucking into port facilities. Thus far, railroads typically regard service to on-dock facilities as more costly than handling traffic in their own yards, especially when the customer is paying for the drayage.[Ref.48] Railroads thus have no incentive to bring domestic containers to on-dock facilities.

There are only a few on-dock rail transfer facilities now handling significant traffic at U.S. ports: Tacoma (two facilities), Portland, Seattle, Long Beach, and New York/New Jersey.[Ref.41] None is yet regarded as congested. In the course of this study it was found that only two, those in Tacoma, regularly handle any domestic containers. With ample current capacity, Maersk and Sea-Land use their on-dock terminals to handle some domestic

backhaul movements intermingled with their international cargo.[Ref.41] It is anticipated that this practice will end when the rise in exports balances the import flows, or when the on-dock transfer facility nears capacity and priority is given to international traffic.

One cause for concern is the double-stack unit trains operated under the control of ocean carriers or multimodal companies. If such trains carried a mix of international and domestic containers into crowded on-dock facilities, the domestic containers would have to be drayed back out. Fortunately, true unit train operations are no longer the rule. Almost all double-stack trains are broken up in-land and reassembled as needed.[Ref.28] Furthermore, much of the domestic traffic solicited by ocean carriers and multimodal companies moves on a mix of trains and schedules separate from the dedicated trains scheduled to coincide with ship arrivals.[Ref.28]

3. Relationships on Container Control

In addition to the overall problem of a larger volume of domestic intermodal traffic and the ability of railroad facilities to handle it, there is a question of control. Just who controls the routing and destination of domestic intermodal traffic, and can or will that party keep it out of crowded marine terminals and on-dock or port area transfer facilities?

Ultimately, the railroad customer controls selection of the railroad and the routing and destination of the traffic. Customers tender traffic at a specific point for movement to a specific point, as permitted by the carriers.

Some rail customers, principally ocean carriers or their subsidiaries, tender both international and domestic traffic for movement via dedicated cars[6] or a completely dedicated train. If the containers are traveling on dedicated cars or dedicated trains, the railroad will simply load, move, and unload the cars according to the customers' instructions. Traffic moving in common-user or other non-dedicated trains and cars, on the other hand, will be loaded, routed, and unloaded in accordance with the railroad's preferences. Domestic movements would not be handled in on-dock facilities unless specifically directed by the customers.

Where the railroads can identify domestic movements and have choice, they can and will keep the bulk of such traffic out of on-dock facilities. Where an ocean carrier or third party controls the movement, and railroads cannot identify domestic movements, the rail customer and the traffic will follow economic and logistic incentives. It will be up to each port, and the operator of any on-dock transfer facilities, to ensure that incentives for rail

[6]Dedicated double-stack cars, are double-stack cars entirely committed to specific rail customers, principally ocean carriers.

customers to route domestic containers into marine facilities are not inadvertently created.

E. SUMMARY

The compatibility issues of international and domestic double-stack container service will not be a hindrance to the expansion of the network, or to efficient service for both types of traffic. However, double-stack operations account for only a part of containerized foreign trade. Besides trying to provide efficient rail transfer facilities, ports must continue to build and improve their marine terminals, the equipment, operations within the terminals, and other projects demanded by port clients. All of the pressures for facilities lead to a shortage of both capital and land at most major ports. Nonetheless, the potential benefits to all parties appear great enough to justify the effort
required to accommodate the increasing container traffic and to resolve compatibility issues.

VI. OVERVIEW OF THE DOUBLE-STACK SYSTEM ECONOMICS

A. INTRODUCTION

A major factor in the success of double-stack container service is its long-haul cost efficiency with respect to both operating cost and equipment investment. The consequent price savings of stacked containers for movement of long-haul freight is impressive and is the number one factor why rail shippers choose double-stack. Figure 6.1 confirms that the price factor stands out as the reason shippers prefer double-stack to piggyback. The figure shows that 70 percent of the shippers surveyed determined that double-stack is better than piggyback with respect to price.

This chapter analyzes the economies of the double-stack container service to see how it compares to long-haul trucking. Since operating cost reflects the potential performance of competing technologies, emphasis is placed on the operating cost incurred with the double-stack system. Appropriate capital costs are also discussed.

Pure line-haul cost is examined first. This includes those cost elements which are only incurred in the line-haul process and are not affected by terminal activities; in this case labor, fuel and locomotive costs. Pure terminal cost is discussed next. For the purposes of this presentation, terminal activities encompass all non line-haul operations,

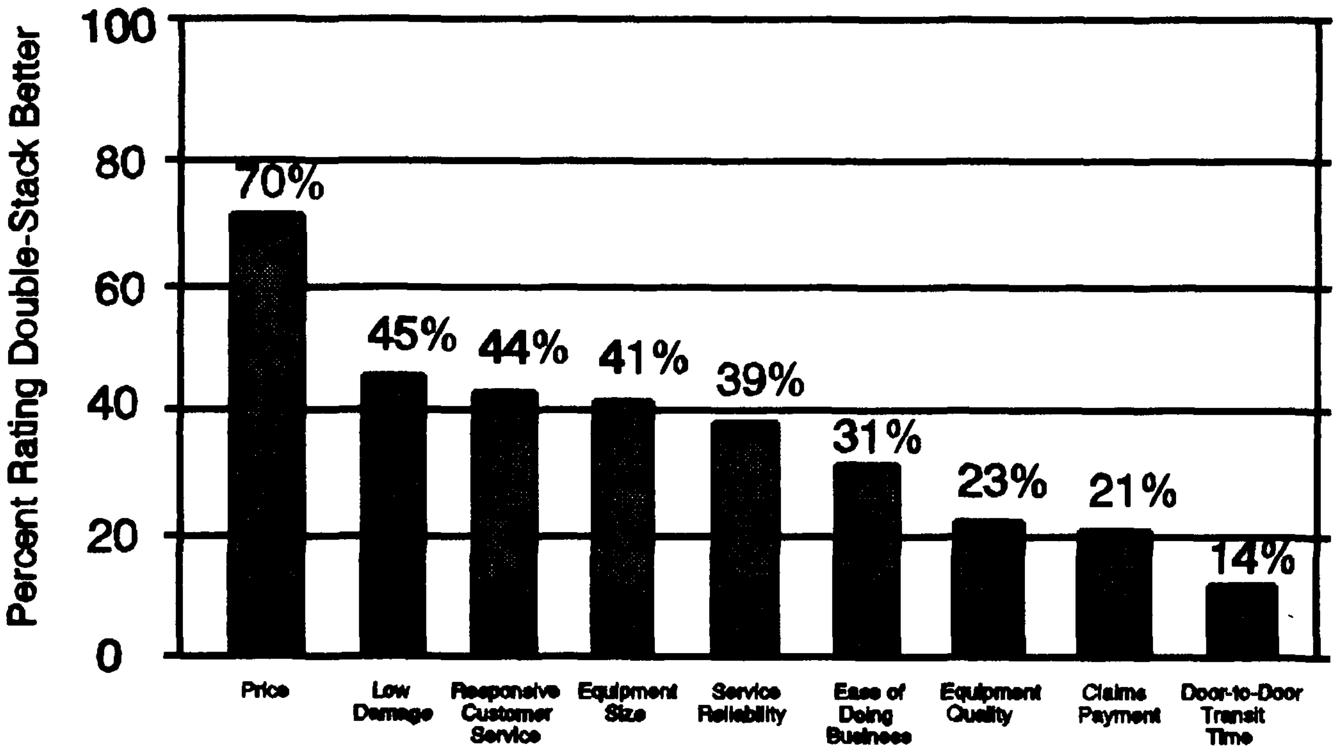


Figure 6.1. Reasons why shippers prefer Double-stack to Piggyback

Source: [Ref.31:p.34]

including the movements between the intermodal terminal and the shipper or receiver. The pure terminal cost elements include terminal lift, chassis cost and drayage cost. Car and container costs, which are affected by both line-haul and terminal activities, are the last cost elements examined. The total line-haul cost and total terminal cost per container are then calculated for two corridors, a long-haul route (Los Angeles-New Orleans, 2010 miles)[2] and a short-haul route (Los Angeles-Oakland, 559 miles). The chapter ends with a concluding discussion concerning the relationship between line-haul length and truck competitiveness.

B. PURE LINE-HAUL COSTS

This section deals with the straight or "pure" line-haul costs. These costs elements are only involved with the line-haul portion of the total operating costs and are affected by the factors associated with incremental distance. The section begins with a discussion of the more important individual cost elements. These include the wages and additional expenses associated with individual crewmen, the effects of crew size on total labor cost, and fuel and

[2].Appendix B gives the shortest rail distance between two points. However, due to clearance requirements of double-stack the shortest route is not necessarily the route taken. In the computation, the best double-stack corridor distance is used for the short-haul and long-haul points.

locomotive costs. To help focus the discussion, cost estimates are developed for each of these elements. Total pure line-haul cost values are then derived for both corridors. These latter values are based on aggregate unit-cost estimates which include additional minor cost elements.

1. Basis of Pay

Labor costs are the most complex factor in the cost estimation, and intermodal operations sometimes have separate labor agreements or other special provisions. Because we will be dealing with through double-stack trains, we will not consider switching between terminals. The three major remaining variables are the basis of pay, the crew size, and the length of crew districts.[Ref.45:p.24] The following discussion and the labor costs used in this example are based on current agreements for a major railroad in the Pacific Northwest, considered typical of industry practice. For simplicity the specific rates chosen are for "new hires."

The basis of pay involves both time and mileage, with the actual pay rate calculated on a mileage basis. The basic day's work is 8 hours and 108 miles. "Overmileage" is paid for miles exceeding 108. "Overtime" is paid for time between 8 hours and 12 hours (the legal limit for on-the-road time), providing mileage also exceeds 108.

Table 6.1 compares pay rates for brakemen, conductors, and engineers. The basis of pay is $0.94 per

TABLE 6.1. TYPICAL PAY RATES FOR NEW HIRE

Type	Brakeman ($ Per Mile)	Conductor ($ Per Mile)	Engineer ($ Per Mile)
Basic Mileage	$0.94	$1.09	$1.31
Overmileage	$0.85	$0.90	$1.08

Source: [Ref.48]

mile for a "new hire" brakeman, once he or she has reached 100 percent pay (pay starts at 75 percent on the date of hire). The minimum day's pay is 108 miles at $0.94 per mile, or $101.52.[Ref.48] Overmileage is paid at about $0.85 per mile. All overtime hours are converted to miles, at 1.5 times the basic rate of 13.5 miles per hour (108 miles in 8 hours), or 20.25 mph.

2. Cost of Crew Size

Labor costs for different crew sizes are presented in Table 6.2. The four-person crew, consisting of two brakemen, a conductor, and an engineer, is still common. The aggregate pay for a four-person crew is about $462.24 per 8-hour/108-mile day, and $3.68 per mile for overmileage. [Ref.48] Reducing the crew to three persons, as has become practical for many intermodal trains, usually involves some additional compensation for the remaining crew members, often called "productivity pay". Typical compensation is about $7.87 per person per trip. Pay rates for a three-person crew plus productivity pay yield about $384.33 per day and $2.83 per mile for overmileage. Some expedited intermodal trains and few double-stack trains operate with two-person crews, just a conductor and an engineer. Pay rates for such a crew, with productivity pay, would be about $274.94 per day and $1.98 per mile for over mileage. The cost for two-person crews represents the minimum feasible labor expense.

TABLE 6.2. RAIL LABOR COST

	2-Person Crew	3-Person Crew	4-Person Crew
Basic Day's Pay	$274.94	$384.33	$462.24
Overmileage	$1.98/mile	$2.83/mile	$3.68/mile
Basic Day's Cost*	$349.17	$488.10	$587.04
Overmileage Cost*	$2.51/mile	$3.59/mile	$4.67/mile

*With 27 percent payroll taxes and benefits.

Source: [Ref.48]

To the basic pay rates discussed above must be added payroll taxes, benefits, and other non-pay labor costs. In the railroad industry, these additional payroll costs are typically 27 percent of the pay; this is also reflected in Table 6.2.

3. Fuel and Locomotive Costs

The fuel and locomotive cost estimates for double-stack trains will be computed using data from Manalytics Incorporated and the Ph.D. dissertation work of Professor David Brown, (one of the thesis advisors) [Ref.50]. Table 6.3 summarizes the results showing that on the Los Angeles-New Orleans route, fuel costs are calculated to be approximately $47 per container for the total distance of 2010 miles. The Los Angeles-Oakland route has a fuel cost of $13 per container for the total distance of 559 miles.

The locomotive costs are based on the GP59 four-axle 3000 horsepower locomotive. "The unit-cost is a simple calculation based on a $1,000,000 initial cost, $60,000 maintenance cost per year, and 85% availability over a 15-year life [Ref.50:p.203]." Table 6.3 summarizes the results showing that on the Los Angeles-New Orleans route, locomotive costs is calculated to be approximately $30 per container. The locomotive cost for the Los Angeles-Oakland route is $9 per container.

TABLE 6.3. FUEL AND LOCOMOTIVE COST

FUEL COST

Units	($/gal)		(HP/Net-Ton)		(Net-Ton/Container)		(Miles)		(gal/HP-Mile)		($/Container)
LA-NO	.3901	x	2.22	x	27.19	x	2010	x	.001	=	47
LA-OAK	.3901	x	2.22	x	27.19	x	559	x	.001	=	13

LOCOMOTIVE COST

Units	($/HP-Hours)		(HP/Net-Ton)		(Net-Ton/Container)		(Hours Line-haul)*		($/Container)
LA-NO	.01	x	2.22	x	27.19	x	50	=	30
LA-OAK	.01	x	2.22	x	27.19	x	14	=	9

Source: [Ref.50]

* Assuming speed of 40 mph.

4. Total Pure Rail Line-Haul Cost

The pure line-haul cost estimates for double-stack trains are based on Manalytics Incorporated data, including some of the previously discussed cost elements [Ref.28]. These total pure line haul cost values include the individual elements examined above (labor, fuel and locomotive costs), plus additional incremental maintenance (@ $0.0012 per gross ton-mile) and other incidental expenses. They are based on operating characteristics, such as locomotive specifications, which are typical of double-stack operations.[Ref. 48]

For both corridors we will assume a normal and attainable standard of 20-car trains, 3-person crews, and extended districts.[3] With an assumed average speed of 40 mph (including intermediate stops), the line-haul costs are $0.124 per container-mile for Los Angeles-New Orleans, and $0.144 for Los Angeles-Oakland.[Ref.48] The per container line-haul cost for Los Angeles-New Orleans is then $249 ($0.124x2010=249.24), while for Los Angeles-Oakland it is $81 ($0.144x559=80.50).

C. PURE TERMINAL COSTS

The pure terminal costs include terminal lift, chassis cost, and drayage cost. These cost elements are associated

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[3]While until very recently, the basis of pay was 100 miles per day, actual crew districts are usually significantly longer (up to several hundred miles).

with activities at the intermodal terminal, or between the terminal and consignee/consignor (to complete the door-to-door service).

1. Chassis Cost

Containers must be placed on chassis for the over-the-road movement behind a truck-tractor. Chassis are also used for container handling in intermodal rail terminals (and at ports). The per chassis costs range from $8.00 to $8.50 per day for most neutral chassis pools. A chassis on long-term leases can be priced as low as $2.00 per day, but long-term leases make the lessee responsible for maintenance, storage, and utilization. The growing popularity of chassis pools suggests that, on balance, the $8.00 to $8.50 range is attractive to all but the largest customers. For the subsequent analysis, the cost per chassis per day is $8.00[Ref.44]. Therefore, the chassis cost for both corridors is $16.00 ($8x2 days) per container.

To keep the cost of a container system (chassis and container) lower, the chassis cannot be used in drayage or storage for more than 75 percent of the total door-to-door time.[Ref.44] This limitation could be a problem in the shortest hauls, where terminal and drayage time together could approach or exceed 75 percent of the total.

2. Cost of Drayage

Intermodal containers must be moveu by highway between inland rail hubs and the actual origins or

destinations. This function known as drayage, is usually provided by specialized firms, often within the commercial zone of a city. The central issue in drayage, or short-haul trucking costs, is the time required to move the intermodal equipment between the shipper (or consignor) and the intermodal rail hub, plus empty back haul time, waiting time, and other delays.

There are five major elements in the underlying cost of highway movements. These costs are: annual cost of truck-tractor ownership; annual cost of tractor maintenance; annual cost of license and insurance; hourly labor cost; and mileage-based fuel cost.[Ref.46:p.124] Four of these five cost elements are based on time, rather than distance.

Annual ownership cost of a drayage tractor (which is not as elaborately equipped as a long-haul tractor) is approximately $14,000; $8,000 for the purchase (an $80,000 purchase price over 10 years, using straight-line depreciation and allowing for no residual) and $6,000 for interest (at a 15% cost of capital). The typical annual cost of maintenance is approximately $16,000. Thus, the annual cost of a fully maintained tractor is about $30,000.[Ref.47] Normal yearly usage is about 225 days per tractor (52 weeks, 5 days per week, less 13 holidays and 22 other days for preventative maintenance, down time and low points in the demand cycle). Daily tractor cost is then $30,000/225, or $133.33 per day in use. For a ten-hour day,

this figure equates to $13.33 per hour. A local non-union driver averages about $11.00 per hour including fringe benefits.[Ref.47] Although some drayage is performed by union drivers, the non-union firms tend to set the competitive rate. Average fuel price of $1.05 per gallon[4], and an average fuel consumption rate of 5.22 miles per gallon overall, yields a fuel cost of $.20 per mile.

The general calculation for the cost of drayage, excluding the cost of the container and chassis, would therefore be:

(($13.33[tractor]+$11.00[labor])xHrs)+($.20[fuel]xMiles)

This equation yields, using 50 miles per hour, an over-the-highway cost of $34.33 per hour, or $.69 per mile, which is nearly the same average as a long-haul truckload carrier. However, relatively little of a drayman's time is spent on inter-city highways, and within urban areas the costs change. Drayage tractors burns fuel at about 1 gallon per hour while idling, and average mileage drops to about 3.5 miles per gallon in urban traffic.[Ref.47] While idling in a terminal, the drayman's cost is about $25.38 per hour, and

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[4] $1.05 is a conservative average of lowest diesel costs from Texico & Shell distributors in California. Prices vary nationwide due to state diesel tax and excise tax.

in urban traffic at 30 miles per hour it is about $33.33 per hour.[Ref.47]

Drayage rates are set to recover the costs of mixed urban and highway movements, for which draymen typically charge a minimum of $35.00 per hour. The strong relationship between time and drayage costs has been observed empirically. In Southern California, for example, drayage over the four miles from the Ports of Los Angeles or Long Beach to the SP Intermodal Container Transfer Facility (ICTF) is roughly $35, reflecting time rather than distance.[Ref.48]

Drayage hours also include time spent waiting in terminals and at the shipper and receiver. Drayage rates usually allow two hours for picking up or dropping off a load. Delay beyond two hours is typically billed at about $32.50 per hour. Time in rail terminals can vary from 15 minutes in the newest and most efficient, to an hour or more in older of congested facilities. Thus, even the shortest trips are often priced at $70 to $80 per round trip to allow for up to two hours of waiting. The low utilization involved in loading, unloading, and waiting yields a very high cost for each mile travelled.

Assuming a drayage distance of up to 30 miles, about half the width of a commercial zone or a metropolitan area, round-trip drayage would require about 4 hours. Then, with

a drayage rate of $35.00, drayage would cost $140 on each end of the trip for a total of $280 for both corridors.

3. Total Pure Terminal Cost

Double-stack services include substantial expenses on both ends of the trip for terminal transfer operations, chassis supply, and drayage. These costs are independent of line-haul trip length, but they can vary substantially between locations.

Industry representatives provided a wide range of estimates for terminal lift costs, and references to other studies widened the range further. The most representative estimate, and the one chosen for use here is $26 per lift for an all-inclusive contract operation (no railroad employees) at a major hub.[Ref.48] This cost does not include amortization of the underlying railroad assets, which was estimated at $8.00 to $10.00 per lift for a large, relatively new facility. Using $8.00 per lift for this amortization, yields a minimum total terminal lift and facility cost of $34.00 per lift.[Ref.48] Therefore, terminal lift is $68 ($34x2 lifts) for both the long-haul and short-haul corridors.

Pure terminal costs per container for both corridors can be summarized as $68 for terminal lift, plus $16 chassis costs, plus drayage costs of $280 for a total of $364.00.

D. CAR AND CONTAINER COSTS

Car and container costs are affected by both line-haul and terminal operations, and are therefore discussed here, separately from the pure line-haul and pure terminal cost elements. In the next section, these car and container costs are used to help calculate total line-haul and terminal cost values.

1. Cost of Double-Stack Cars

Currently, Trailer Train is the major source of double-stack cars. Moreover, railroad officials and supplier contracts agreed that Trailer Train's rates serve as a benchmark for the industry.[Ref.33:p.18] The Trailer Train rate generally includes a per diem charge and a mileage charge. These are full-service rates, including both time-based and mileage-based maintenance. The most recent Trailer Train double-stack purchases are "heavy lift" cars, with 125-ton trucks, capable of handling 20-foot to 48-foot containers in all wells.[5] The current rate per car is $69.84 per day and $0.065 per mile, per car [Ref.44]. Assuming a full carload of ten 48-foot containers, this rate equates to a cost of $6.98 per day and $0.0065 per mile for each 48-foot container unit. Table 6.4 summarizes these car

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[5]As mentioned earlier, 53-foot containers can be stacked on top, however, for simplicity we will assume all containers used for cost determination are 48-foot.

TABLE 6.4. LINE-HAUL RAIL CAR COST

Type (Container Unit=CU)	Per Day ($ Per CU)	Per Mile ($ Per CU)	Total CU * Mileage Equivalent ($ Per CU)
Double-Stack (DTTX)	$6.98	$.0065	$.0138
Piggyback (TTWX)	$5.16	$.0150	$.0204

*Total Container Unit (CU) mileage equivalent is computed assuming speed of 40 mph averaged over a 24 hour day.

Source: [Ref.44]

costs and indicates the corresponding costs for TOFC equipment. The mileage rates in Table 6.4 also reflect differences in maintenance expense for each type of car. The differences in mileage costs are more significant on the long hauls which typify intermodal movements. Assuming a 2,000 mile haul, the difference between $0.0065 per mile and $0.015 per mile comes to $17.00 per unit between double-stack and piggyback. The table also shows a line-haul total mileage equivalent, including per diem, at 40 mph for a 24-hour day.

The per diem charges for Trailer Train cars apply to time spent in terminals as well as time spent on the road. If a double-stack car spends 12 hours in the terminal at each end of the line-haul, it would accumulate 24 hours of terminal time for each one-way trip. For double-stack cars, this per diem implies a fixed cost of $6.98 per container space per trip in addition to the variable line-haul costs. For conventional piggyback cars, this fixed terminal cost is $5.16 per trailer space.[Ref.44]

Figure 6.2 displays the relationship between total railroad rolling stock costs (line-haul plus terminal) and length of haul for double-stack and conventional piggyback cars. Space per container on the double-stack car has a higher fixed cost (on the vertical axis), but progressively lower per-mile container costs because of its lower mileage

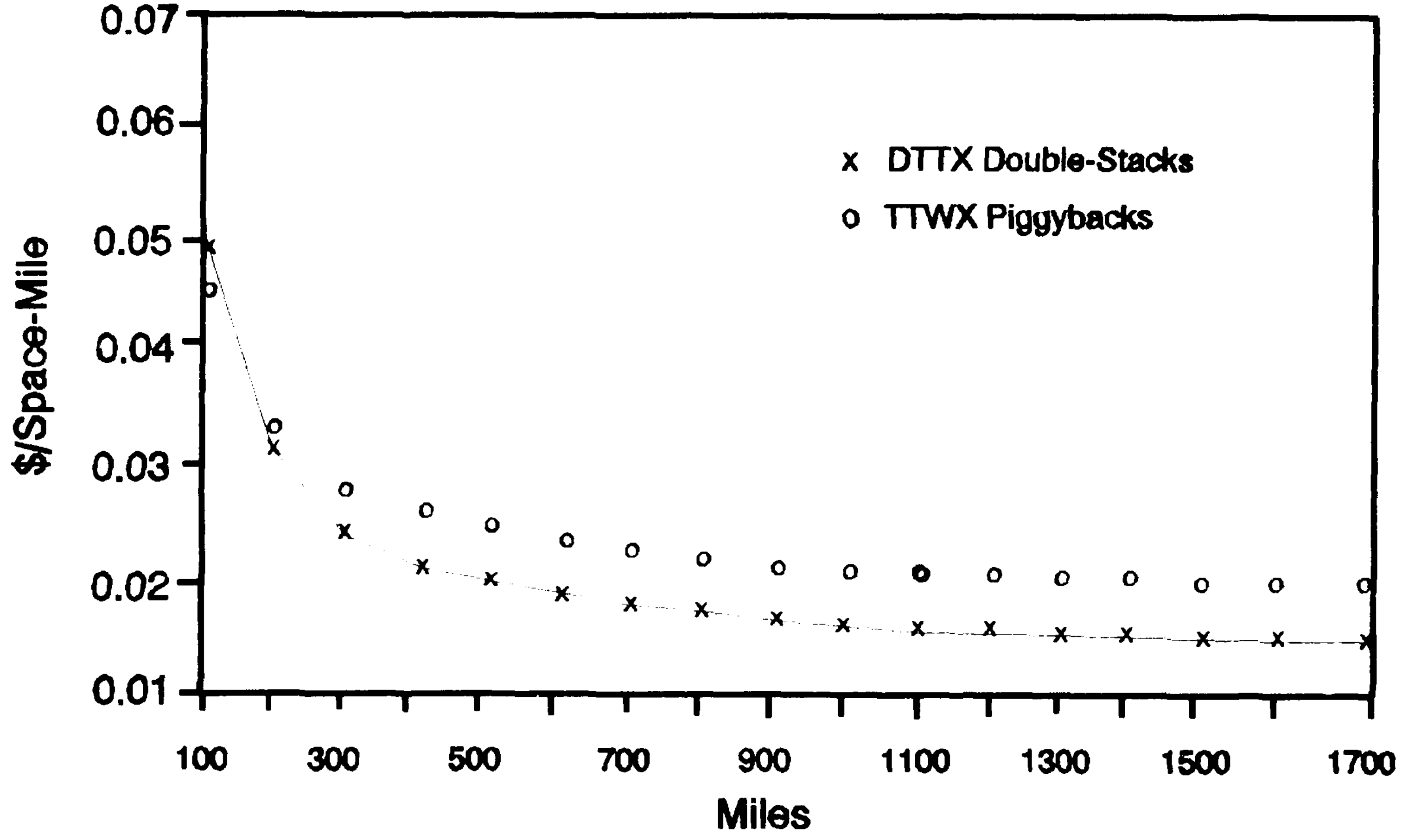

Figure 6.2. Rail Car Cost ($/Space-Mile)

Source: [Ref.46]

charge. Both curves drop sharply between 100 and 700 miles, the effect of allocating the fixed terminal per diem expense over a progressively longer line-haul. Once the length of haul exceeds 700-900 miles, the curves are nearly flat with double-stack cars having a lower cost per space mile.

Returning to our double-stack long-haul versus short-haul comparison, a Los Angeles-New Orleans door-to-door move requires two days of line-haul. Therefore, line-haul car costs are ($6.98x2)+($.0065x2010) =$27.03 ($27 rounded) per container. Similarly, for a Los Angeles-Oakland move, a one-day line-haul implies line-haul car costs of ($6.98x1)+($.0065x559) =$10.61 ($11 rounded). For both corridors, terminal car costs are $6.98 ($7 rounded) per container.

2. Cost of Containers

Containers or trailers are generally obtained either from short-term leasing pools such as those managed by Trailer Train, or through long-term leases which, from an operating point of view, are equivalent to out-right ownership. The daily costs of containers and trailers can differ significantly, as shown with Table 6.5.[Ref.44] Both the pool and lease costs in Table 6.5 include maintenance; the pool costs also include storage while long-term leases do not. The greatest differences between pool and long-term lease are risk and utilization. The use of pool equipment entails no risk, no management, and no responsibility when

TABLE 6.5. REPRESENTATIVE CONTAINER AND TRAILER DAILY COSTS

Type	Pool ($ Per CU)	Lease ($ Per CU)	Breakeven Utilization
48' x 8.5' Container	$6.50	$4.90	75%
48' x 8.5' Trailer	$12.50	$7.25	58%

Source: [Ref.44]

the equipment is not used. However, long-term lease or out-right ownership does entail risk, management, and the responsibility for seeing that the unit achieves acceptable utilization. Large carriers or multi-modals that can accept risk, usually manage the equipment effectively and thereby achieve high utilization. Such carriers can obtain significant savings by either a long-term lease or out-right ownership of the equipment.[Ref.45:p.23]

Using the pool cost, the per diem on a 48-foot x 8.5-foot container is $6.50 per day.[Ref.44] For the Los Angeles-New Orleans move the container cost is $32.50. This cost is broken down into a line-haul container cost of $13 ($6.50x2 days) and a terminal container cost of $19.50 (including time for pick-up and delivery). The container cost for the Los Angeles-Oakland move is $22.75 ($3.25 for line-haul and $19.50 for terminal activities).

E. TOTAL COST DOOR-TO-DOOR MOVEMENT

To obtain the total cost of a door-to-door double-stack movement, one must add pure line-haul costs, pure terminal costs and, finally, car and container costs. Table 6.6 summarizes the total costs for door-to-door double-stack transport using the values computed earlier. Recall that these values are based on calculations assuming a 20-car train, 3-person crew, with extended districts for both routes. Line haul car costs assume two days for Los Angeles-New Orleans and one day for Los Angeles-Oakland.

TABLE 6.6. DOUBLE-STACK TOTAL OPERATING COST

	LA-New Orleans		LA-Oakland	
Pure Line-Haul Costs	$249		$81	
Line-Haul Car Costs	27		11	
Line-Haul Container Costs	13		3	
Total Line-Haul Costs		$289		$95
Pure Terminal Costs	$364		$364	
Terminal Car Costs	7		7	
Terminal Container Costs	20		20	
Total Terminal Costs		$391		$391
Total Operating Costs		$680		$486
Line-Haul $/Space Mile	680/2010 = .34		486/559 = .87	

Container costs assumes five days for Los Angeles-New Orleans (one day to load and pickup, two days line-haul, one day at the terminal, and one day to deliver and unload) and three days for Los Angeles-Oakland (one day to load, one day line-haul and at the terminal, and one day to unload). All terminal costs are the same for both corridors.

Table 6.6 reflects a dramatic difference in cost per mile for the two corridors. This is consequence of the length of the haul. Although the unit line-haul costs are slightly higher for shorter hauls, the big difference is in the allocation of fixed costs over the line-haul miles. The estimated fixed costs of terminal lift, chassis, drayage and terminal car/container use total $391 per container. Over 2010 miles, this fixed cost averages $.19 per mile. Over 559 miles, this fixed cost averages $.70 per mile.

In the long-haul corridor (Los Angeles-New Orleans) the total cost per container-mile ($.34) is clearly competitive with truckload costs (at $0.71 per mile), even if a rate discount is offered by the trucker [Ref.44]. Indeed, there is little disagreement that double-stack operations have a marked cost advantage over trucks for such long hauls.[Ref.33:p.15]

For the short-haul corridor (Los Angeles-Oakland) the total door-to-door cost is $.87 per container-mile under the assumptions given above. The Los Angeles-Oakland trip yields a value that is not competitive with truckload costs

(at $.71 per mile). This analysis indicates that the break-even distance between double-stack and over-the-road trucking is about 710 miles.

F. DOUBLE-STACK VERSUS TRUCK

Railroad and truck mileage from origin to destination are seldom the same due to the highway and track layout. In many instances the variation is far enough apart to affect the ability of railroads to compete on short hauls. On long hauls, the cost advantage is great enough, and the transit time long enough, for the railroads to overcome a significant degree of variation. However, the distance variation between track and road, as a percentage of total distance, tends to decline as length of haul increases. The highway distance between Los Angeles and New Orleans is roughly 1883 miles, 7 percent less than the rail distance of 2010 miles (see Appendix B). On shorter hauls, however, the difference can be significant. The distance over Southern Pacific's Central Valley route between Oakland and Los Angeles (used for SP's priority trains and thus for our cost analysis) is 559 miles. The highway distance is around 379 miles or 32 percent less. The railroad cannot be cost-competitive on that route.

Appendix B compares rail and truck (highway) distances for some 200 city pairs representing major intermodal candidates. The rail mileage is actually shorter in a handful of cases (e.g., Chicago-Memphis or Kansas City-

Detroit). On average, however, rail mileage are about 8 percent longer than truck mileage.

When drayage is limited to the commercial zone, a double-stack train with a line-haul of 725 miles can be truck-competitive.[Ref.42:p.22] Figure 6.3 indicates the tradeoff between line-haul and drayage distance with respect to competitiveness. The area under the line where double-stacks are competitive assumes highly efficient operations and 100 percent loaded containers and cars in both directions. Only the most successful double-stack operators approach such cost and utilization assumptions. However, these standards must be approached by double-stack services seeking to be competitive with trucks on hauls as short as 700 miles.[Ref.42:p.23]

This finding coincides with the results of the 1977 Census of Transportation, which found little rail market share in hauls of less than 500 miles; 83 percent of the intercity merchandise was moved by motor carrier in this short haul market.[Ref.49:p.135] Roughly 11 percent of rail traffic was found to be in the 500-999 mile range where, in particular, this study found double-stack service to be truck-competitive. The remaining 6 percent of intercity movement was in hauls of 1,000 miles or more. As this chapter has shown double-stacks appear to have an advantage and, as a consequence, railroads have been found to hold a larger market share which continues to grow.[Ref.33:p.19]

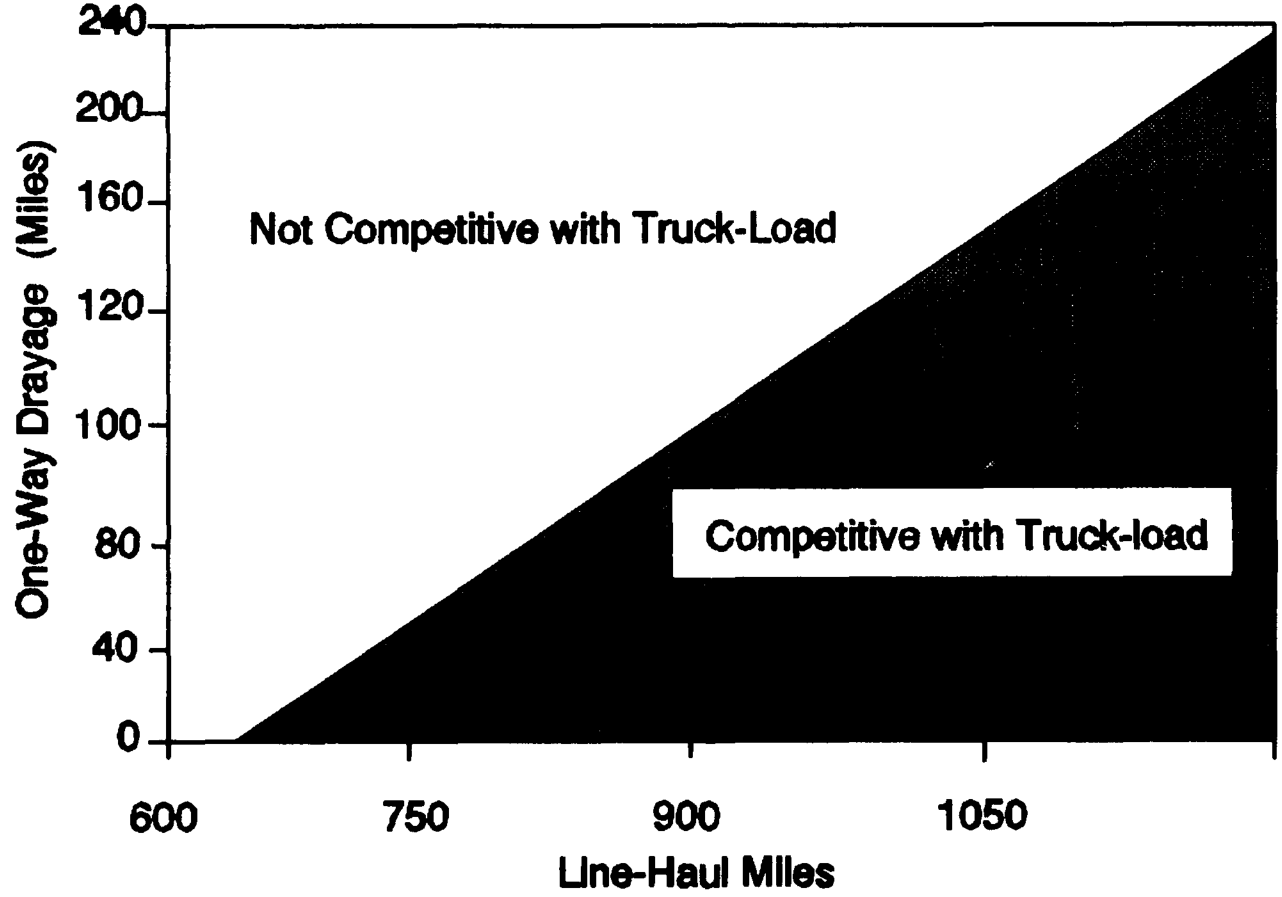

Figure 6.3. Competitive Rail Line-Haul, Considering Drayage and Length of Haul for Double-Stack

Source:[Ref.46]

VII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The research shows that there is an enormous growth potential of double-stack container systems, particularly in domestic freight. Containers facilitate smooth transition between modes of travel, and double-stack trains provide quick dependable transportation on the long-haul land leg.

Within the intermodal industry, double-stacked containers can be efficiently used to quickly and safely transport virtually any commodity or cargo. The double-stack network shows promise that it may be able to resolve the problem of fragmentation which has prevented intermodal service from becoming truck-competitive.

Through the investigation process for this thesis, it was determined that containerization, especially the double stack container system, has affected the shipper's perception of domestic intermodal transportation as an alternative to trucks. Double-stack service is growing and exhibits cost competitiveness with trucking in dense traffic corridors. Opportunities exist for introducing stack trains in less dense corridors, as in outlying areas between major hubs.

The compatibility issues of international and domestic double-stack containers and services was discussed. These

issues will probably not create a hindrance to the expansion of the network, or to efficient service for both types of traffic. However, there are still numerous problems to be overcome, and solutions will require time, money, and management attention.

B. CONCLUSION

Shifting trade patterns and globalization have creating new opportunities for intermodalism. It is time for intermodal transportation to seize the new opportunities and potential profits with respect to shippers looking for dependable, high-quality, value-added service.

Full realization of the double-stack potential may require the railroad industry to take unaccustomed steps into marketing, sales, and customer service. The alternative is to become strictly line-haul contract carriers, and rely on third parties or ocean carrier affiliates for marketing, customer service, door-to-door management, and perhaps even terminal operations.

For ports and ocean carriers, the implications are mixed. Ports will be under continuous competitive pressure to accommodate international double-stack growth, but will be only indirectly affected by domestic containerization. Ocean carriers, too, will be subject to competitive pressure, but may find new opportunities in meshing their international container movements with a growing domestic double-stack service.

This thesis identifies several obstacles to achieving that potential. None is insurmountable, but all will require sustained commitment of resources and management attention to one objective: provision of improved, reliable, door-to-door service. Some obstacles are technical, involving the features of double-stack cars and containers, the efficiency and reliability of operations, and the accommodation of new traffic patterns. The more serious obstacles, and those requiring the most immediate attention, tend to involve marketing, management, and organization.

In order to be competitive, the intermodal firm must meet changing customer needs with comprehensive, precise, reliable and timely transportation, while also providing total logistics management services. Today, customers desire flexible, responsive transportation with matching networks that can take materials and products around the world, not only port-to-port but door-to-door. The newest player in the intermodal transportation industry is the multimodal firm which can offer integrated double-stack service with truck-competitive transit times and door-to-door delivery.

C. RECOMMENDATIONS

Greater awareness of the benefits available from double-stack train service and its equipment is highly recommended for all military personnel involved in or dealing with the transportation industry. Awareness of double-stack train

routes opens a new avenue for negotiating for the commercial movement of military cargo in volume point-to-point rates, thereby, saving in long-haul transportation costs.

The military should invest in research and development of specialized containers which will meet ISO (Organization for International Standards) standards and, in addition, meet specific military needs. By containerizing the bulk of military cargo, mobilization can be streamlined and double-stack trains can be used for most long-haul transfers at a considerable savings.

APPENDIX A

INTERMODAL HUB VOLUMES FOR YEAR 2000
BASED ON COMBINED INTERMODAL, BOXABLE, AND TRAM DIVERSION FEUS
DATA SOURCES: ICC CARLOAD WAYBILL SAMPLE WITH ASSUMED 4 PERCENT ANNUAL GROWTH AND TRAM TRUCK DIVERSIONS

BEA NUMBER AND NAME	FEUS ORIGINATED	FEUS TERMINATED	TOTAL FEU VOLUME
1 BANGOR, ME	733	133	866
2 PORTLAND-LEWISTON, ME	134	669	803
3 BURLINGTON, VT	4,236	3,723	7,959
4 BOSTON, MA	120,011	202,758	322,769
6 HARTFORD-NEW HAVEN-SPRINGFLD, CT-MA	49,485	54,672	104,157
7 ALBANY-SCHENECTADY-TROY, NY	24,037	20,915	44,952
8 SYRACUSE-UTICA, NY	33,259	16,388	49,647
9 ROCHESTER, NY	49,215	14,196	63,411
10 BUFFALO, NY	38,192	36,838	75,030
11 BINGHAMTON-ELMIRA, NY	601	1,666	2,267
12 NEW YORK, NY	507,453	623,809	1,131,262
14 WILLIAMSPORT, PA	167	0	167
15 ERIE, PA	7,692	7,368	15,060
16 PITTSBURGH, PA	20,678	25,824	46,502
17 HARRISBURG-YORK-LANCASTER, PA	37,637	75,109	112,746
18 PHILADELPHIA, PA	183,302	306,250	489,552
19 BALTIMORE, MD	108,076	170,425	278,501
20 WASHINGTON, DC	84,318	160,663	244,981
21 ROANOKE-LYNCHBURG, VA	1,667	1,800	3,467
22 RICHMOND, VA	4,330	6,061	10,391
23 NORFOLK-VIRGINIA BCH-NEWPT NEWS, VA	92,544	92,520	185,064
24 ROCKY MNT-WILSON-GREENVILLE, NC	2,331	1,865	4,196
25 WILMINGTON, NC	9,725	8,192	17,917
26 FAYETTEVILLE, NC	533	0	533
28 GREENSBORO-WINSTON-SALEM-HIGHPNT, NC	23,578	22,915	46,493
29 CHARLOTTE, NC	36,604	38,298	74,902
30 ASHEVILLE, NC	4,897	3,597	8,494
31 GREENVILLE-SPARTANBURG, SC	11,391	9,196	20,587
34 CHARLESTON-NORTH CHARLESTON, SC	85,303	104,129	189,432
35 AUGUSTA, GA	4,396	866	5,262
36 ATLANTA, GA	235,913	203,259	439,172
37 COLUMBUS, GA	2,999	1,598	4,597
38 MACON, GA	33,506	8,264	41,770
39 SAVANNAH, GA	92,731	99,108	191,839
40 ALBANY, GA	3,799	1,134	4,933
41 JACKSONVILLE, FL	235,996	253,162	489,158
42 ORLANDO-MELBOURNE-DAYTONA BEACH, FL	34,834	56,947	91,781
43 MIAMI-FORT LAUDERDALE, FL	139,615	289,837	429,452
44 TAMPA-ST. PETERSBURG, FL	25,378	64,272	89,650
46 PENSACOLA-PANAMA CITY, FL	666	301	967
47 MOBILE, AL	43,993	24,399	68,392
48 MONTGOMERY, AL	11,259	4,533	15,792
49 BIRMINGHAM, AL	72,096	67,442	139,538
50 HUNTSVILLE-FLORENCE, AL	8,327	5,529	13,856
51 CHATTANOOGA, TN	36,234	19,786	56,020
52 JOHNSON CTY-KINGSPT-BRISTOL, TN-VA	24,776	15,922	40,698
53 KNOXVILLE, TN	5,665	6,597	12,262
54 NASHVILLE, TN	48,819	39,764	88,583
55 MEMPHIS, TN	299,794	236,622	536,416

APPENDIX A

INTERMODAL HUB VOLUMES FOR YEAR 2000
BASED ON COMBINED INTERMODAL, BOXABLE, AND TRAM DIVERSION FEUS
DATA SOURCES: ICC CARLOAD WAYBILL SAMPLE WITH ASSUMED 4 PERCENT ANNUAL GROWTH AND TRAM TRUCK DIVERSIONS

BEA NUMBER AND NAME	FEUS ORIGINATED	FEUS TERMINATED	TOTAL FEU VOLUME
56 PADUCAH, KY	1,833	2,300	4,133
57 LOUISVILLE, KY	52,585	43,391	95,976
58 LEXINGTON, KY	1,603	1,934	3,537
65 CLEVELAND, OH	58,865	67,179	126,044
66 COLUMBUS, OH	71,226	55,289	126,515
67 CINCINNATI, OH	93,172	73,994	167,166
70 TOLEDO, OH	38,987	25,729	64,716
71 DETROIT, MI	171,940	163,002	334,942
72 SAGINAW-BAY CITY, MI	0	167	167
73 GRAND RAPIDS, MI	3,664	866	4,530
74 LANSING-KALAMAZOO, MI	0	7,368	7,368
75 SOUTH BEND, IN	200	167	367
76 FORT WAYNE, IN	9,553	1,731	11,284
78 ANDERSON-MUNCIE, IN	0	134	134
79 INDIANAPOLIS, IN	9,760	13,219	22,979
80 EVANSVILLE, IN	13,651	7,529	21,180
82 LAFAYETTE, IN	7,387	13,434	20,821
83 CHICAGO, IL	2,215,015	2,017,302	4,232,317
84 CHAMPAIGN-URBANA, IL	466	267	733
85 SPRINGFIELD-DECATUR, IL	8,860	0	8,860
86 QUINCY, IL	200	0	200
87 PEORIA, IL	29,610	18,537	48,147
88 ROCKFORD, IL	0	6,501	6,501
89 MILWAUKEE, WI	18,287	16,988	35,275
90 MADISON, WI	1,868	334	2,202
91 LA CROSSE, WI	133	0	133
92 EAU CLAIRE, WI	1,466	1,166	2,632
93 WAUSAU, WI	1,166	1,833	2,999
94 APLETON-GREEN BAY-OSHKOSH, WI	16,321	13,190	29,511
95 DULUTH, MN	0	134	134
96 MINNEAPOLIS-ST. PAUL, MN	146,326	181,346	327,672
99 DAVENPORT-ROCK ISLAND-MOLINE, IA-IL	20,875	1,940	22,815
100 CEDAR RAPIDS, IA	14,681	1,334	16,015
101 WATERLOO, IA	200	0	200
102 FORT DODGE, IA	799	0	799
103 SIOUX CITY, IA	1,599	167	1,766
104 DES MOINES, IA	55,194	27,378	82,572
105 KANSAS CITY, MO	328,572	285,131	613,703
107 ST. LOUIS, MO	333,829	263,508	597,337
108 SPRINGFIELD, MO	16,589	20,075	36,664
110 FORT SMITH, AR	11,590	1,998	13,588
111 LITTLE ROCK-N. LITTLE ROCK, AR	50,770	40,362	91,132
112 JACKSON, MS	11,291	17,654	28,945
113 NEW ORLEANS, LA	229,040	268,817	497,857
114 BATON ROUGE, LA	5,664	735	6,399
116 LAKE CHARLES, LA	3,910	3,798	7,708
117 SHREVEPORT, LA	5,631	5,216	10,847
118 MONROE, LA	0	67	67
119 TEXARKANA, TX	6,961	3,864	10,825

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BASED ON COMBINED INTERMODAL, BOXABLE, AND TRAM DIVERSION FEUS
DATA SOURCES: ICC CARLOAD WAYBILL SAMPLE WITH ASSUMED 4 PERCENT
ANNUAL GROWTH AND TRAM TRUCK DIVERSIONS

BEA NUMBER AND NAME	FEUS ORIGINATED	FEUS TERMINATED	TOTAL FEU VOLUME
120 TYLER-LONGVIEW, TX	16,088	6,796	22,884
121 BEAUMONT-PORT ARTHUR, TX	23,838	667	24,505
122 HOUSTON, TX	268,254	351,195	619,449
123 AUSTIN, TX	167	17,861	18,028
124 WACO-KILLEEN-TEMPLE, TX	1,299	999	2,298
125 DALLAS-FORT WORTH, TX	488,595	524,888	1,013,483
127 ABILENE, TX	67	0	67
129 SAN ANTONIO, TX	61,877	51,160	113,037
130 CORPUS CHRISTI, TX	301	1,532	1,833
131 BROWNSVILLE-MCALLEN-HARLINGEN, TX	6,062	2,906	8,968
132 ODESSA-MIDLAND, TX	9,111	67	9,178
133 ELPASO, TX	38,158	29,559	67,717
134 LUBBOCK, TX	3,975	5,316	9,291
135 AMARILLO, TX	36,407	25,608	62,015
137 OKLAHOMA CITY, OK	12,263	31,085	43,348
138 TULSA, OK	24,587	27,597	52,184
139 WICHITA, KS	34,685	17,156	51,841
141 TOPEKA, KS	9,284	9,566	18,850
142 LINCOLN, NE	18,022	8,836	26,858
143 OMAHA, NE	101,688	108,657	210,345
144 GRAND ISLAND, NE	200	12,348	12,548
145 SCOTTSBLUFF, NE	400	666	1,066
146 RAPID CITY, SD	1,332	0	1,332
147 SIOUX FALLS, SD	0	67	67
149 FARGO-MOORHEAD, ND-MN	7,261	6,063	13,324
150 GRAND FORKS, ND	4,262	333	4,595
153 GREAT FALLS, MT	867	1,267	2,134
154 MISSOULA, MT	13,828	666	14,494
155 BILLINGS, MT	8,261	7,060	15,321
156 CHEYENNE-CASPER, WY	16,145	3,330	19,475
157 DENVER, CO	92,215	142,976	235,191
158 COLORADO SPRINGS-PUEBLO, CO	134	1,166	1,300
159 GRAND JUNCTION, CO	300	2,165	2,465
160 ALBUQUERQUE, NM	13,043	62,511	75,554
161 TUCSON, AZ	2,031	15,699	17,730
162 PHOENIX AZ	102,225	290,181	392,406
163 LAS VEGAS, NV	1,865	4,197	6,062
164 RENO, NV	10,329	79,402	89,731
165 SALT LAKE CITY-OGDEN, UT	69,189	162,876	232,065
166 POCATELLO-IDAHO FALLS, ID	2,266	866	3,132
167 BOISE CITY, ID	3,865	1,752	5,617
168 SPOKANE, WA	41,928	54,736	96,664
169 RICHLAND, WA	55,757	24,740	80,497
170 YAKIMA, WA	56,548	15,190	71,738
171 SEATTLE, WA	556,373	588,411	1,144,784
172 PORTLAND, OR	373,967	394,191	768,158
173 EUGENE, OR	88,817	535	89,352
174 REDDING, CA	67	67	134
176 SAN FRANCISCO-OAKLAND-SAN JOSE, CA	406,286	648,293	1,054,579

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BASED ON COMBINED INTERMODAL, BOXABLE, AND TRAM DIVERSION FEUS
DATA SOURCES: ICC CARLOAD WAYBILL SAMPLE WITH ASSUMED 4 PERCENT ANNUAL GROWTH AND TRAM TRUCK DIVERSIONS

BEA NUMBER AND NAME	FEUS ORIGINATED	FEUS TERMINATED	TOTAL FEU VOLUME
177 SACRAMENTO, CA	124,782	72,256	197,038
178 STOCKTON-MODESTO, CA	282,371	113,880	396,251
179 FRESNO-BAKERSFIELD, CA	203,575	59,974	263,549
180 LOS ANGELES, CA	1,810,753	1,553,448	3,364,201
181 SAN DIEGO, CA	7,273	5,011	12,284
185 MARITIMES	3,797	0	3,797
186 QUEBEC	95,344	0	95,344
187 ONTARIO	41,562	18,321	59,883
188 MANITOBA	2,499	0	2,499
189 SASKATCHEWAN	333	0	333
190 ALBERTA	6,394	0	6,394
191 BRITISH COLUMBIA	19,851	5,529	25,380
192 PUERTO RICO	733	0	733

APPENDIX B

	Atlanta			Chicago			Dallas		
	Rail	Highway	R/H	Rail	Highway	R/H	Rail	Highway	R/H
Atlanta				734	674	1.09	825	795	1.04
Baltimore	676	645	1.05	796	668	1.19	1448	1356	1.07
Boston	1091	1037	1.05	1018	963	1.06	1864	1748	1.07
Chicago	734	674	1.09				968	917	1.06
Cleveland	750	672	1.12	340	335	1.01	1234	1159	1.06
Dallas	825	795	1.04	968	917	1.06			
Denver	1526	1398	1.09	1026	996	1.03	835	781	1.07
Detroit	748	699	1.07	272	266	1.02	1200	1143	1.05
Houston	856	789	1.08	1205	1067	1.13	264	243	1.09
Indianapolis	585	493	1.19	184	181	1.02	951	865	1.10
Jacksonville	350	306	1.14	1083	980	1.11	1096	990	1.11
Kansas City	890	798	1.12	451	499	0.90	517	489	1.06
Los Angeles	2285	2182	1.05	2227	2054	1.08	1460	1387	1.05
Memphis	420	371	1.13	527	530	0.99	481	452	1.06
Miami	716	655	1.09	1449	1329	1.09	1462	1300	1.12
New Orleans	493	479	1.03	921	912	1.01	506	496	1.02
New York	862	841	1.02	908	802	1.13	1635	1552	1.05
Philadelphia	771	741	1.04	816	738	1.11	1543	1452	1.06
Pittsburgh	806	687	1.17	468	452	1.04	1291	1204	1.07
St Louis	612	541	1.13	284	289	0.98	711	630	1.13
St Paul	1130	1063	1.06	396	395	1.00	997	938	1.06
San Francisco	2718	2496	1.09	2263	2142	1.06	1930	1753	1.10
Seattle	2824	2618	1.08	2141	2013	1.06	2394	2078	1.15
AVERAGE RAIL CIRCUITY		1.088			1.053			1.075	

	Jacksonville			Kansas City			Los Angeles		
	Rail	Highway	R/H	Rail	Highway	R/H	Rail	Highway	R/H
Atlanta	350	306	1.14	890	798	1.12	2285	2182	1.05
Baltimore	794	763	1.04	1198	1048	1.14	2908	2636	1.10
Boston	1210	1155	1.05	1469	1391	1.06	3244	2979	1.09
Chicago	1083	980	1.11	451	499	0.90	2227	2054	1.08
Cleveland	1100	915	1.20	791	779	1.02	2555	2367	1.08
Dallas	1096	990	1.11	517	489	1.06	1460	1387	1.05
Denver	1811	1704	1.06	636	600	1.06	1353	1059	1.28
Detroit	1098	1003	1.09	723	743	0.97	2499	2311	1.08
Houston	975	889	1.10	781	710	1.10	1641	1538	1.07
Indianapolis	935	799	1.17	518	485	1.07	2272	2073	1.10
Jacksonville				1175	1104	1.06	2578	2377	1.08
Kansas City	1175	1104	1.06				1776	1589	1.12
Los Angeles	2578	2377	1.08	1776	1589	1.12			
Memphis	691	674	1.03	484	451	1.07	1942	1817	1.07
Miami	366	349	1.05	1541	1448	1.06	2944	2687	1.10
New Orleans	612	555	1.10	873	806	1.08	1966	1883	1.04
New York	981	959	1.02	1329	1198	1.11	3082	2786	1.11
Philadelphia	890	859	1.04	1237	1118	1.11	2991	2706	1.11
Pittsburgh	1052	851	1.24	889	838	1.06	2643	2426	1.09
St Louis	917	847	1.08	278	257	1.08	2032	1845	1.10
St Paul	1479	1369	1.08	480	449	1.07	2157	1894	1.14
San Francisco	2989	2743	1.09	1970	1835	1.07	470	379	1.24
Seattle	3129	2924	1.07	1954	1839	1.06	1370	1131	1.21
AVERAGE RAIL CIRCUITY		1.092			1.066			1.108	

APPENDIX B

New Orleans

	Rail	Highway	R/H
Atlanta	493	479	1.03
Baltimore	1154	1115	1.03
Boston	1569	1507	1.04
Chicago	921	912	1.01
Cleveland	1096	1030	1.06
Dallas	506	496	1.02
Denver	1341	1273	1.05
Detroit	1094	1045	1.05
Houston	363	356	1.02
Indianapolis	858	796	1.08
Jacksonville	612	555	1.10
Kansas City	873	806	1.08
Los Angeles	1966	1883	1.04
Memphis	394	390	1.01
Miami	978	856	1.14
New Orleans			
New York	1355	1311	1.03
Philadelphia	1264	1211	1.04
Pittsburgh	1152	1070	1.08
St Louis	699	673	1.04
St Paul	1273	1209	1.05
San Francisco	2436	2249	1.08
Seattle	2900	2574	1.13
AVERAGE RAIL CIRCUITY		1.056	

New York

	Rail	Highway	R/H
Atlanta	862	841	1.02
Baltimore	187	196	0.95
Boston	229	206	1.11
Chicago	908	802	1.13
Cleveland	571	473	1.21
Dallas	1635	1552	1.05
Denver	1934	1771	1.09
Detroit	648	637	1.02
Houston	1703	1608	1.06
Indianapolis	811	713	1.14
Jacksonville	981	959	1.02
Kansas City	1329	1198	1.11
Los Angeles	3082	2786	1.11
Memphis	1153	1100	1.05
Miami	1347	1308	1.03
New Orleans	1355	1311	1.03
New York			
Philadelphia	91	100	0.91
Pittsburgh	439	368	1.19
St Louis	1051	948	1.11
St Paul	1304	1197	1.09
San Francisco	3171	2934	1.08
Seattle	2739	2815	0.97
AVERAGE RAIL CIRCUITY		1.068	

San Francisco

	Rail	Highway	R/H
Atlanta	2718	2496	1.09
Baltimore	3059	2796	1.09
Boston	3281	3095	1.06
Chicago	2263	2142	1.06
Cleveland	2603	2467	1.06
Dallas	1930	1753	1.10
Denver	1374	1235	1.11
Detroit	2535	2399	1.06
Houston	2111	1912	1.10
Indianapolis	2429	2256	1.08
Jacksonville	2989	2743	1.09
Kansas City	1970	1835	1.07
Los Angeles	470	379	1.24
Memphis	2298	2125	1.08
Miami	3355	3053	1.10
New Orleans	2436	2249	1.08
New York	3171	2934	1.08
Philadelphia	3079	2866	1.07
Pittsburgh	2731	2578	1.06
St Louis	2189	2089	1.05
St Paul	2123	1945	1.09
San Francisco			
Seattle	900	808	1.11
AVERAGE RAIL CIRCUITY		1.088	

Seattle

	Rail	Highway	R/H
Atlanta	2824	2618	1.08
Baltimore	2937	2681	1.10
Boston	3159	2976	1.06
Chicago	2141	2013	1.06
Cleveland	2481	2348	1.06
Dallas	2394	2078	1.15
Denver	1554	1307	1.19
Detroit	2413	2279	1.06
Houston	2656	2274	1.17
Indianapolis	2325	2194	1.06
Jacksonville	3125	2924	1.07
Kansas City	1954	1839	1.06
Los Angeles	1370	1131	1.21
Memphis	2438	2290	1.06
Miami	3495	3273	1.07
New Orleans	2900	2574	1.13
New York	3049	2815	1.08
Philadelphia	2957	2751	1.07
Pittsburgh	2610	2465	1.06
St Louis	2213	2081	1.06
St Paul	1745	1618	1.08
San Francisco	900	808	1.11
Seattle			
AVERAGE RAIL CIRCUITY		1.094	

OVERALL AVERAGE RAIL CIRCUITY 1.079

LIST OF REFERENCES

1. Cavinato, J.L., Transportation-Logistics Dictionary, 3rd ed., p.113, International Thomson Transport Press, 1990.

2. Dunlap, C., "Intermodal Marriage Is An Uneasy One," Journal of Commerce, p.58, 15 June 1989.

3 Smith D.S., Double Stack Container Systems: Implications for U.S. Railroads and Ports, pp.5-17, U.S. Department of Transportation, June 1990.

4. Pike, E., "Expo Speakers See Bright Future for Intermodal," Container News, pp.16-18, July 1990.

5. Mahoney, J.H., Intermodal Freight Transportation, pp.5-10, Eno Foundation for Transportation, 1985.

6. Whitehurst, C.H., The Defense Transportation System, pp.111-113, American Enterprise Institute, 1976.

7. Sampson, R.J., Farris, M.T., Schrock, D.L., Domestic Transportation: Practice, Theory, and Policy, 6th ed., p.328, Houghton Mifflin Company, 1990.

8. Fahrenwald, B., "RoadRailer: The Emerging Alternative," Intermodal Age, p.16, 1987.

9. Muller, G., Intermodal Freight Transportation, 2nd ed., p.49, Eno Foundation for Transportation, pp.31-176, 1989.

10. Martin, D.J., "Container Loadings Tip The Scales," Container News, pp.18-19, November 1990.

11. Neshiem, P.R., The Impact on Military Containerization of a Trend By the Civilian Sector Towards 40 Foot Containers, Master's Thesis, Naval Postgraduate School, Monterey, California, December 1984.

12. Ryan, L., "Overcapacity, Big Ships Seen Continuing in 1990", Journal of Commerce, p.1a, 22 September 1989.

13. U.S. Department of Transportation, Maritime Administration, U.S. Oceanborne Foreign Trade Routes, pp.6-13, September 1989.

14. Gibson, D., Hollingshead, C., and Williams, E., "New Shipping Patterns Affect Mobilization Potential," Defense

Transportation Journal, p.17, April 1988.

15. Atkins, W.H., Modern Marine Terminal Operations and Management, The Compage Company, p.102, 1983.

16. Hudson, J. and Baker, F., "The Current Surface Transport Interrelationships Affecting Intermodal Growth," Proceedings of the Transportation Research Forum, vol.26, no.1, p.251, 1985.

17. James, D., "Profitable Utilization of Air/Surface Containers," Transport 2000, p.45. May/June 1989.

18. Coyle, J., Bardi, E., and Cavinato, J., Transportation, West Publishing Company, pp.53-242, 1990.

19 "Intermodal Loadings Rise in October," Container News, p.16, December 1991.

20. DOD Directive No. 4500.37, Subject: Management of the DOD Intermodal Container System, dtd 2 April 1987.

21. "Slump, War Pinch Container Supplies", Journal of Commerce, p.12, 2 February 1991.

22. "Surprise War Impact: A Box Shortage?" Shipping Digest, p.27, 4 February 1991.

23. Hall, K.G., "Bush signs Highway Bill in Texas, says it will Create 'jobs, jobs, jobs'", Traffic World, p.13, 23 December 1991.

24. Roe, R.A., "New Intermodal System As Policy Centerpiece," Advocates, p.69, 10 December 1991.

25. Cohan, P., "Proof of Intermodal is in the Customer Base," Container News, pp.14-15, August 1990.

26. Abbott, J., "Where Third Parties Come First," Containerization International, pp.35-36, January 1991.

27. "Intermodal's Future: Perils and Promise", Railway Age, p.24, May 1991.

28. Telephone conversation between Vick Daning, Trailer Train (TTX), and the author, 15 February 1992.

29. Anderson, D.L., U.S. Intermodal Developments: Double-Stack Rail Car Services, Proceedings of Container Efficiency and Shipping Conference, pp.103-109, 2 December 1985.

30. Canna, E., "Stack Train Intermodalism: Who Is Running The

Show?" American Shipper, vol.29, no.12, p.40, December 1987.

31. MacDonald, M.E., "How Intermodal Stacks Up," Traffic Management, p.34, May 1991.

32. McKenzie, D., "Towards the Ultimate Double-Stack," Cargo Systems International, vol.13, no.8, p.61, August 1988.

33. Pike, E., "The Emerging Intermodal Industry," Container News, pp.16-19, October 1990.

34. "American President Lines, Transway, SP and BN Begin Trailer Balancing Program," Modern Railroads, vol.38, no.8, p.61, August 1988.

35. "U.S. Maritime Fleet Ready for War, Eyes Further Call to Military Service," Traffic World, p.34, 21 January 1991.

36. Hayashi, G., "Intermodalism Pays Off in the Gulf War," Defense Transportation Journal, p.64-66, June 1991.

37. Ingram, R.S., "Burlington Container Decision," Continerization International, vol.22, no.6, p.49, June 1988.

38. McKenzie, D., "The challenge of Double-Stacks," Cargo Systems International, Intermodal Supplement, p.54, December 1989.

39. Knee, R., "Should Ports Run Their Own Stack Trains?," American Shipper, vol.30, no.8, p.22, August 1988

40. Branch, A.E., Elements of Port Operation and Management, pp.22-25, Chapmen and Hall, 1986.

41. Telephone conversation between Edward Reade, Sea-Land HQ (Dallas), and the author, 26 February 1992.

42. Borzo, G., "Domestic Turmoil, The Container's Role," Modern Railroads, vol.45, no.14, pp.22-23, August 1990.

43. "CSX Seeking ICC Approval to Acquire Kentucky Coal Line," Traffic World, p.26, January 1992.

44. Telephone conversation between Robert Danchik, Trailer Train, and the author, 20 February 1992.

45 Greenwood, W.E., "Improving the Profitability of the Intermodal Industry," Intermodal Forum, pp.23-24, Summer 1987.

46 Association of American Railroads, Domestic

Containerization: A Feasibility Study, p.124, Temple, Barker and Sloane Inc., February 1986.

47 Telephone conversation between John Hauws, Ryder Commercial Distributers and author, 28 February 1992.

48 Telephone conversation between John Bowers, Southern Pacific and author, 26 February 1992.

49 US Bureau of the Census, 1977 Census of Transportation, Washington, D.C., p.135, 1977.

50. Brown, D.G., Optimal Freight Service Quality and Impications for Economic Analysis, Inventory-Theoretic Shipper Cost Functions and Run-Through Train Operations, PH.D. Dissertation, University of Illinois, Urbana-Champaign, Illinois, 1988.

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